IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

INTERDIGITAL COMMUNICATIONS CORP., INTERDIGITAL TECHNOLOGY CORP., Plaintiffs, v. SAMSUNG ELECTRONICS CO., LTD. SAMSUNG ELECTRONICS AMERICA, INC., and SAMSUNG TELECOMMUNICATIONS AMERICA LLC, Defendants.	)	Civil Action No.: 07-165 JJF **JURY TRIAL DEMANDED**

FIRST AMENDED COMPLAINT

This is an action for patent infringement. Plaintiffs, InterDigital Communications Corporation and InterDigital Technology Corporation (collectively "InterDigital"), through their undersigned counsel, bring this action against Defendants, Samsung Electronics Co., Ltd., Samsung Electronics America, Inc., and Samsung Telecommunications America LLC (collectively "the Samsung Defendants"). Pursuant to Federal Rule of Civil Procedure 15(a), Plaintiffs amend the Complaint as a matter of course, no responsive pleading having been yet served. In support of this First Amended Complaint, InterDigital alleges as follows:

THE PARTIES

1. Plaintiff, InterDigital Communications Corporation ("InterDigital Communications"), is a Pennsylvania corporation, having its principal place of business at 781 Third Avenue, King of Prussia, Pennsylvania 19406-1409.

2. Plaintiff, InterDigital Technology Corporation ("InterDigital Technology"), is a Delaware corporation, having its principal place of business at Hagley

Building, Suite 105, 3411 Silverside Road, Concord Plaza, Wilmington, Delaware 19810-4812. InterDigital Communications is the parent company to InterDigital Technology.

3. Defendant, Samsung Electronics Co., Ltd. ("Samsung Electronics"), is a Korean corporation, having its principal place of business at Samsung Main Building, 250, Taepyung-ro 2-ka, Chueng-ku, Seoul 100-742 Korea.

4. Defendant, Samsung Electronics America, Inc. ("SEA"), is a New York corporation, having its principal place of business at 105 Challenger Road, Ridgefield Park, New Jersey 07660. SEA is a wholly owned subsidiary of Samsung Electronics.

5. Defendant, Samsung Telecommunications America LLC ("STA"), is a Delaware corporation, having its principal place of business at 1301 Lookout Drive, Richardson, Texas 75082. STA is a wholly own subsidiary of Samsung Electronics. Upon information and belief, Samsung Telecommunications America LLP converted to Samsung Telecommunications America LLC on December 27, 2006.

JURISDICTION AND VENUE

6. This is an action for patent infringement arising under the patent laws of the United States. This Court has jurisdiction over this action under 28 U.S.C. §§ 1331 and 1338(a).

7. Venue is proper in this judicial district under 28 U.S.C. §§ 1391(c)-(d) and 1400(b).

FACTUAL BACKGROUND

8. United States Letters Patent No. 7,117,004 ("the '004 patent"), entitled "Method and Subscriber Unit for Performing an Access Procedure," issued on October 3, 2006, to inventors Fatih Ozluturk and Gary Lomp. InterDigital Technology owns by assignment the

entire right, title, and interest in and to the ’004 patent. A true and correct copy of the ’004 patent is attached to this First Amended Complaint as Exhibit A.

9. United States Letters Patent No. 6,674,791 (“the ’791 patent”), entitled “Automatic Power Control System for a Code Division Multiple Access (CDMA) Communications System,” issued on January 6, 2004, to inventors Gary Lomp, Fatih Ozluturk, and John Kowalski. InterDigital Technology owns by assignment the entire right, title, and interest in and to the ’791 patent. A true and correct copy of the ’791 patent is attached to this First Amended Complaint as Exhibit B.

10. United States Letters Patent No. 6,973,579 (“the ’579 patent”), entitled “Generation of User Equipment Identification Specific Scrambling Code for the High Speed Shared Control Channel,” issued on December 6, 2005, to inventors Stephen G. Dick, Nader Boulourchi, and Sung-Hyuk Shin. InterDigital Technology owns by assignment the entire right, title, and interest in and to the ’579 patent. A true and correct copy of the ’579 patent is attached to this First Amended Complaint as Exhibit C.

11. United States Letters Patent No. 7,190,966 (“the ’966 patent”), entitled “Method and Apparatus for Performing an Access Procedure,” issued on March 13, 2007, to inventors Fatih Ozluturk and Gary R. Lomp. InterDigital Technology owns by assignment the entire right, title, and interest in and to the ’966 patent. A true and correct copy of the ’966 patent is attached to this First Amended Complaint as Exhibit D.

FIRST CAUSE OF ACTION
INFRINGEMENT OF U.S. PATENT NO. 7,117,004

12. The ’004 patent is presumed valid under 28 U.S.C. § 282, and remains enforceable.

13. On information and belief, the Samsung Defendants manufacture, use,

import, offer for sale, and/or sell products in the United States that infringe the ’004 patent, and will continue to do so unless enjoined by this Court.

14. On information and belief, the Samsung Defendants manufacture, import, offer to sell, and/or sell in the United States the following Third Generation (“3G”) Wideband Code Division Multiple Access (“WCDMA”) handsets and components thereof that infringe the ’004 patent: (1) SGH-ZX20, (2) SGH-i607 (sometimes referred to as the “Blackjack”), (3) SGH-A707 (sometimes referred to as the “Sync”), and (4) SGH-ZX10. The identification of these specific models is not intended to limit the scope of the First Amended Complaint, and any remedy should extend to all infringing models.

15. The Samsung Defendants’ past and continuing infringements of the ’004 patent have caused irreparable damage to InterDigital, and will continue to do so unless enjoined by this Court.

SECOND CAUSE OF ACTION
INFRINGEMENT OF U.S. PATENT NO. 6,674,791

16. The ’791 patent is presumed valid under 28 U.S.C. § 282, and remains enforceable.

17. On information and belief, the Samsung Defendants manufacture, import, offer for sale, and/or sell products in the United States that infringe the ’791 patent, and will continue to do so unless enjoined by this Court.

18. On information and belief, the Samsung Defendants manufacture, use, import, offer for sale, and/or sell in the United States the following Third Generation (“3G”) Wideband Code Division Multiple Access (“WCDMA”) handsets and components thereof that infringe the ’791 patent: (1) SGH-ZX20, (2) SGH-i607 (sometimes referred to as the “Blackjack”), (3) SGH-A707 (sometimes referred to as the “Sync”), and (4) SGH-ZX10. The

identification of these specific models is not intended to limit the scope of the First Amended Complaint, and any remedy should extend to all infringing models.

19. The Samsung Defendants know or should have known of InterDigital's rights in the '791 patent, and their infringement of the '791 patent has been willful and deliberate.

20. The Samsung Defendants' past and continuing infringements of the '791 patent have caused irreparable damage to InterDigital, and will continue to do so unless enjoined by this Court.

THIRD CAUSE OF ACTION
INFRINGEMENT OF U.S. PATENT NO. 6,973,579

21. The '579 patent is presumed valid under 28 U.S.C. § 282, and remains enforceable.

22. On information and belief, the Samsung Defendants manufacture, use, import, offer for sale, and/or sell products in the United States that infringe the '579 patent, and will continue to do so unless enjoined by this Court.

23. On information and belief, the Samsung Defendants manufacture, import, offer for sale, and/or sell in the United States the following Third Generation ("3G") Wideband Code Division Multiple Access ("WCDMA") handsets and components thereof that infringe the '579 patent: (1) SGH-ZX20, (2) SGH-i607 (sometimes referred to as the "Blackjack"), and (3) SGH-A707 (sometimes referred to as the "Sync"). The identification of these specific models is not intended to limit the scope of the First Amended Complaint, and any remedy should extend to all infringing models.

24. The Samsung Defendants know or should have known of InterDigital's rights in the '579 patent, and their infringement of the '579 patent has been willful and

deliberate.

25. The Samsung Defendants' past and continuing infringements of the '579 patent have caused irreparable damage to InterDigital, and will continue to do so unless enjoined by this Court.

FOURTH CAUSE OF ACTION
INFRINGEMENT OF U.S. PATENT NO. 7,190,966

26. The '966 patent is presumed valid under 28 U.S.C. § 282, and remains enforceable.

27. On information and belief, the Samsung Defendants manufacture, use, import, offer for sale, and/or sell products in the United States that infringe the '966 patent, and will continue to do so unless enjoined by this Court.

28. On information and belief, the Samsung Defendants manufacture, import, offer to sell, and/or sell in the United States the following Third Generation ("3G") Wideband Code Division Multiple Access ("WCDMA") handsets and components thereof that infringe the '004 patent: (1) SGH-ZX20, (2) SGH-i607 (sometimes referred to as the "Blackjack"), (3) SGH-A707 (sometimes referred to as the "Sync"), and (4) SGH-ZX10. The identification of these specific models is not intended to limit the scope of the First Amended Complaint, and any remedy should extend to all infringing models.

29. The Samsung Defendants' past and continuing infringements of the '966 patent have caused irreparable damage to InterDigital, and will continue to do so unless enjoined by this Court.

PRAYER FOR RELIEF

30. WHEREFORE, InterDigital respectfully requests that this Court:

(a) Find that the Samsung Defendants have infringed one or more claims of the ’004 patent, the ’791 patent, the ’579 patent and the ’966 patent;

(b) Find that this is an exceptional case under 35 U.S.C. § 285;

(c) Preliminarily and permanently enjoin the Samsung Defendants from infringing the ’004 patent, the ’791 patent, the ’579 patent and the ’966 patent under 35 U.S.C. § 283;

(d) Award InterDigital an amount to be determined as compensatory damages for the infringement of the ’004 patent, the ’791 patent, the ’579 patent and the ’966 patent and the costs of the action, as fixed by the Court, under 35 U.S.C. § 284;

(e) Treble the damages resulting from the Samsung Defendants’ willful and deliberate infringement of the ’791 patent and the ’579 patent under 35 U.S.C. § 284;

(f) Award InterDigital its costs, including expenses and reasonable attorneys’ fees, incurred in bringing and prosecuting this action under 35 U.S.C. § 285;

(g) Award InterDigital prejudgment and post judgment interest on all amounts awarded; and

(h) Award InterDigital any further relief that this Court deems just and proper.

JURY DEMAND

31. InterDigital demands a jury trial as to all issues that are triable by a jury in this action.

Dated: May 7, 2007

/s/ Richard K. Herrmann

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EXHIBIT A

US007117004B2

(12) **United States Patent**
Ozluturk et al.

(10) **Patent No.: US 7,117,004 B2**
(45) **Date of Patent: *Oct. 3, 2006**

(54) METHOD AND SUBSCRIBER UNIT FOR PERFORMING AN ACCESS PROCEDURE

(75) Inventors: **Fatih M. Ozluturk**, Port Washington, NY (US); **Gary R. Lomp**, Centerport, NY (US)

(73) Assignee: **InterDigital Technology Corporation**, Wilmington, DE (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **10/866,851**

(22) Filed: **Jun. 14, 2004**

(65) **Prior Publication Data**

US 2004/0242259 A1 Dec. 2, 2004

Related U.S. Application Data

(63) Continuation of application No. 10/400,343, filed on Mar. 26, 2003, now Pat. No. 6,839,567, which is a continuation of application No. 10/086,320, filed on Mar. 1, 2002, now Pat. No. 6,571,105, which is a continuation of application No. 09/721,034, filed on Nov. 22, 2000, now Pat. No. 6,493,563, which is a continuation of application No. 09/003,104, filed on Jan. 6, 1998, now Pat. No. 6,181,949, which is a continuation of application No. 08/670,162, filed on Jun. 27, 1996, now Pat. No. 5,841,768.

(51) **Int. Cl.**
H04B 1/00 (2006.01)

(52) **U.S. Cl.** **455/522**; 455/69; 455/63.11; 370/335; 370/342; 370/278

(58) **Field of Classification Search** 455/522, 455/63.11, 69, 517, 507; 370/335, 342, 394, 370/395.2, 395.21, 514, 278, 491
See application file for complete search history.

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Rick et al., "Noncoherent Parallel Acquisition in CDMA Spread Spectrum Systems," IEEE International Conference on New Orleans LA, USA, May 1-5, 1994, New York, NY, USA, IEEE, pp. 1422-1426.

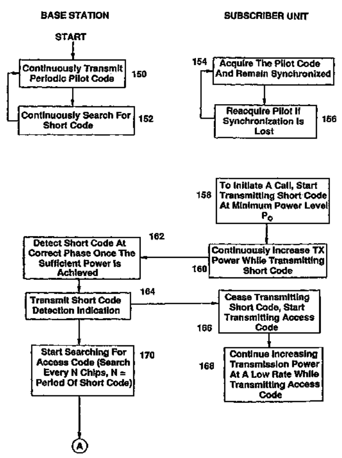
(Continued)

Primary Examiner—Lana Le
(74) *Attorney, Agent, or Firm*—Volpe and Koenig, P.C.

(57) **ABSTRACT**

A base station for controlling transmission power during the establishment of a communication channel utilizes the reception of a short code during initial power ramp-up. The short code is a sequence for detection by the base station which has a much shorter period than a conventional access code. The ramp-up starts from a power level that is lower than the required power level for detection by the base station. The power of the short code is quickly increased until the signal is detected by the base station. Once the base station detects the short code, it transmits an indication that the short code has been detected.

66 Claims, 11 Drawing Sheets



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2005/0249166	A1	*	11/2005	Ozluturk et al.	370/342
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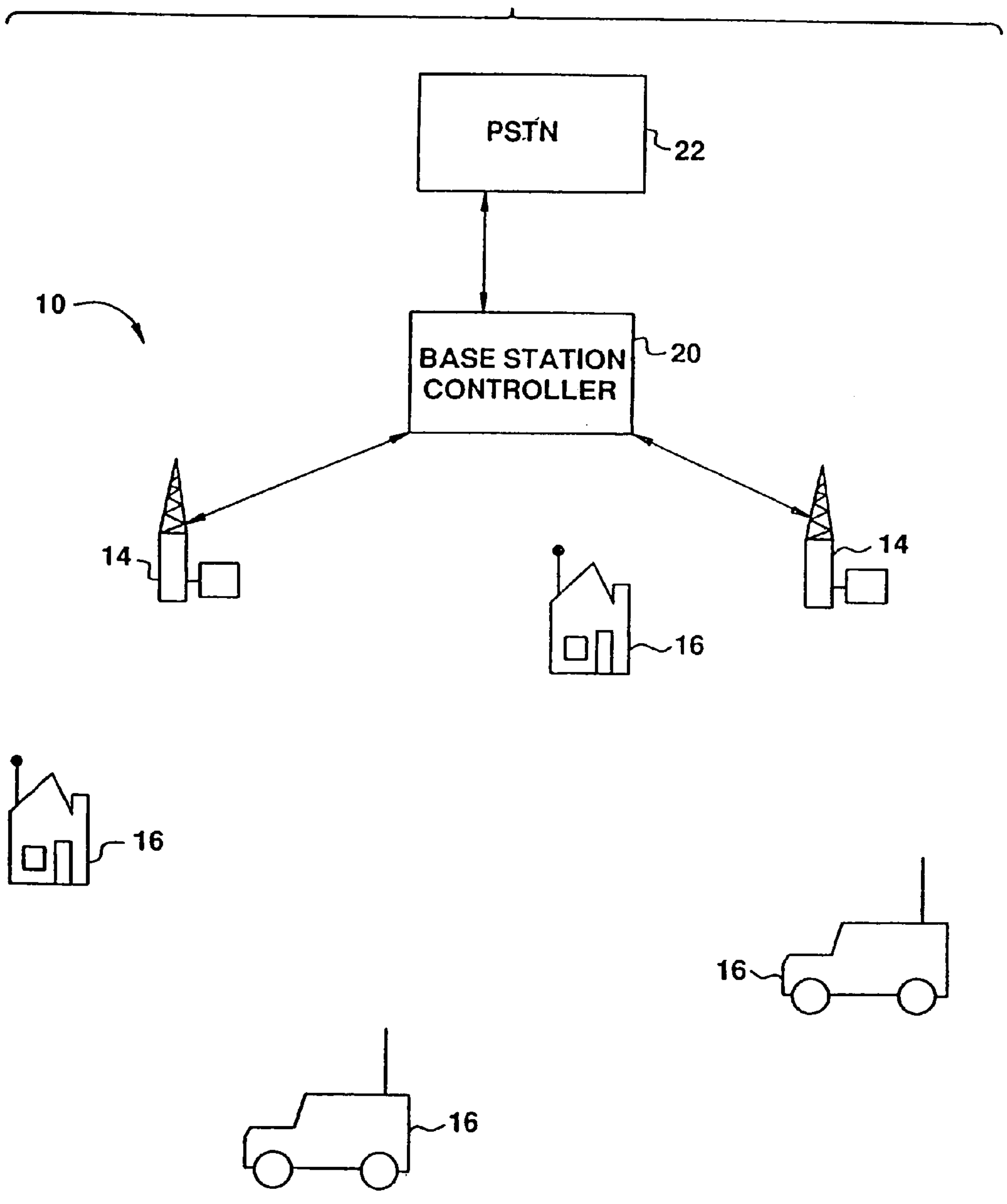
FIG.1



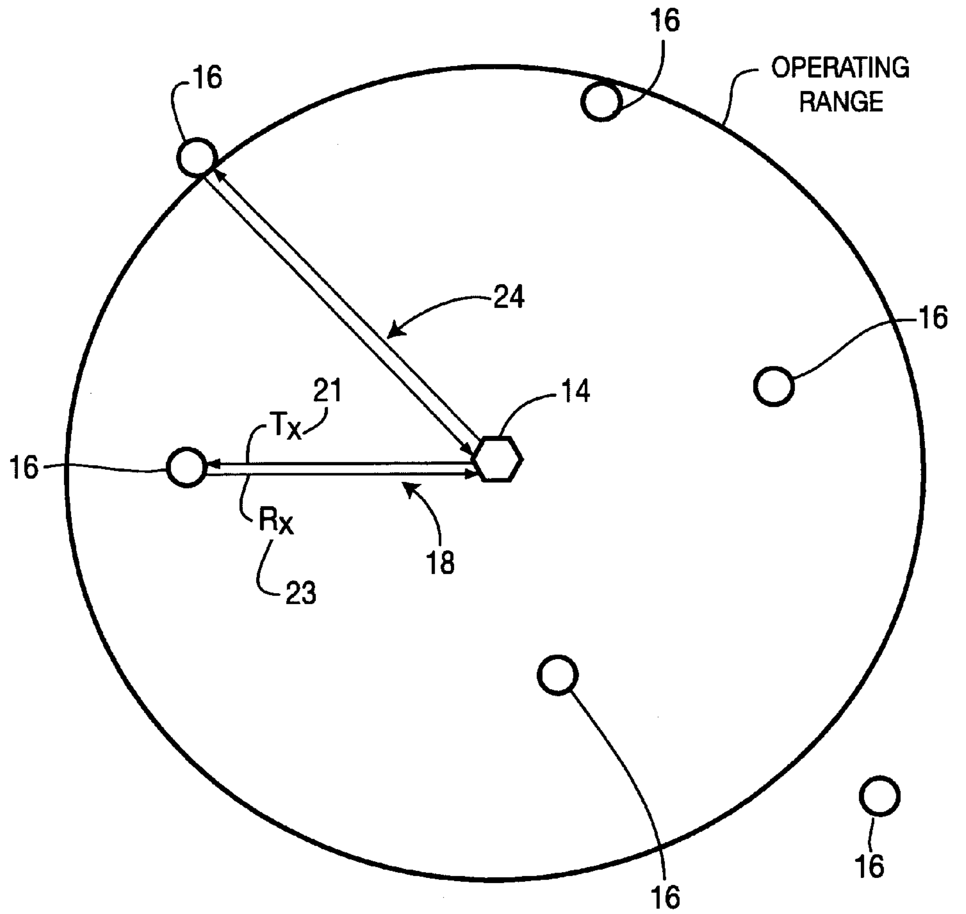


FIG. 2

FIG.3

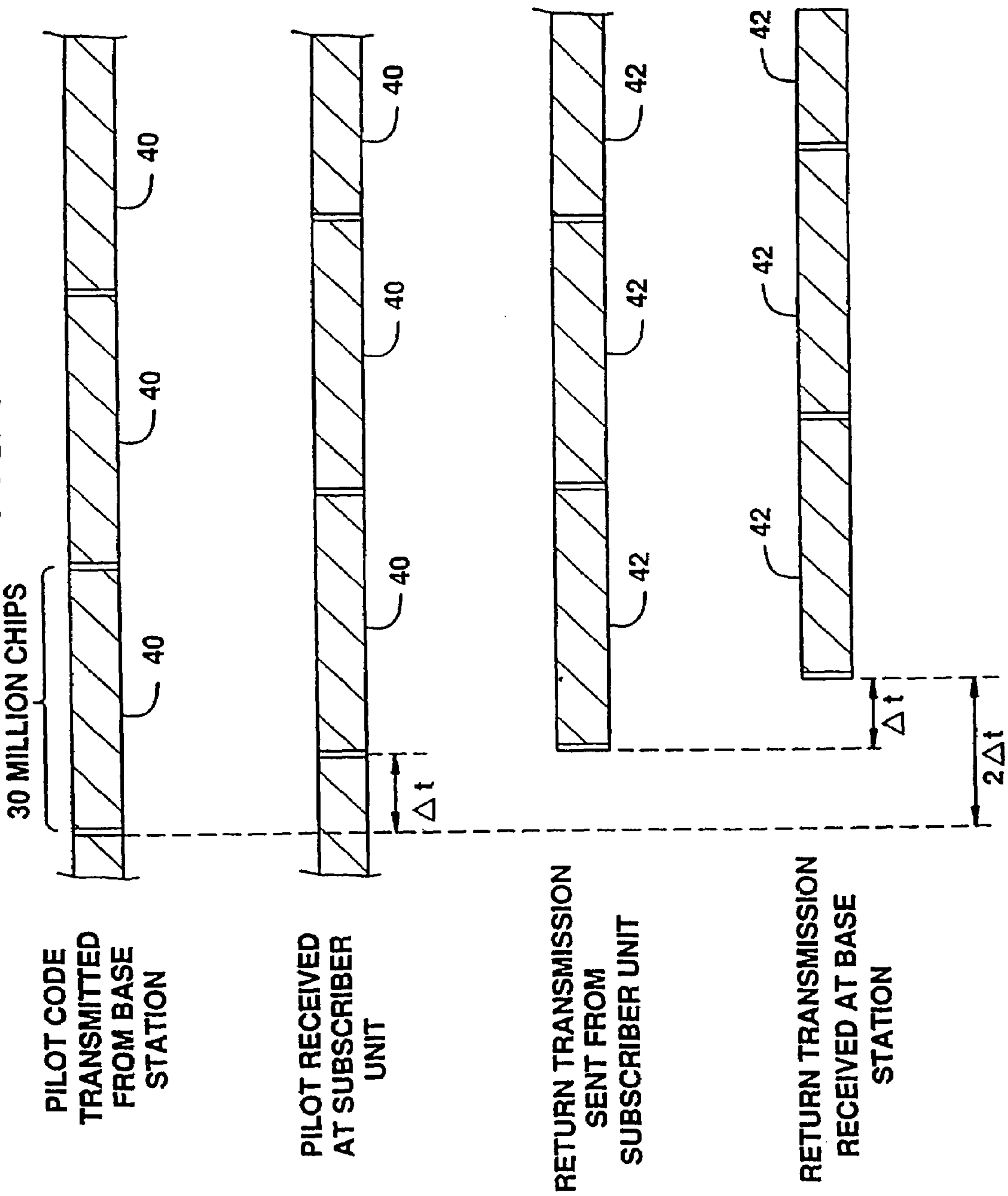

30 MILLION CHIPS
40
40
40
40
40
40
42
42
42
42
42
42
Δt
Δt
2Δt
PILOT CODE TRANSMITTED FROM BASE STATION
PILOT RECEIVED AT SUBSCRIBER UNIT
RETURN TRANSMISSION SENT FROM SUBSCRIBER UNIT
RETURN TRANSMISSION RECEIVED AT BASE STATION

FIG.4

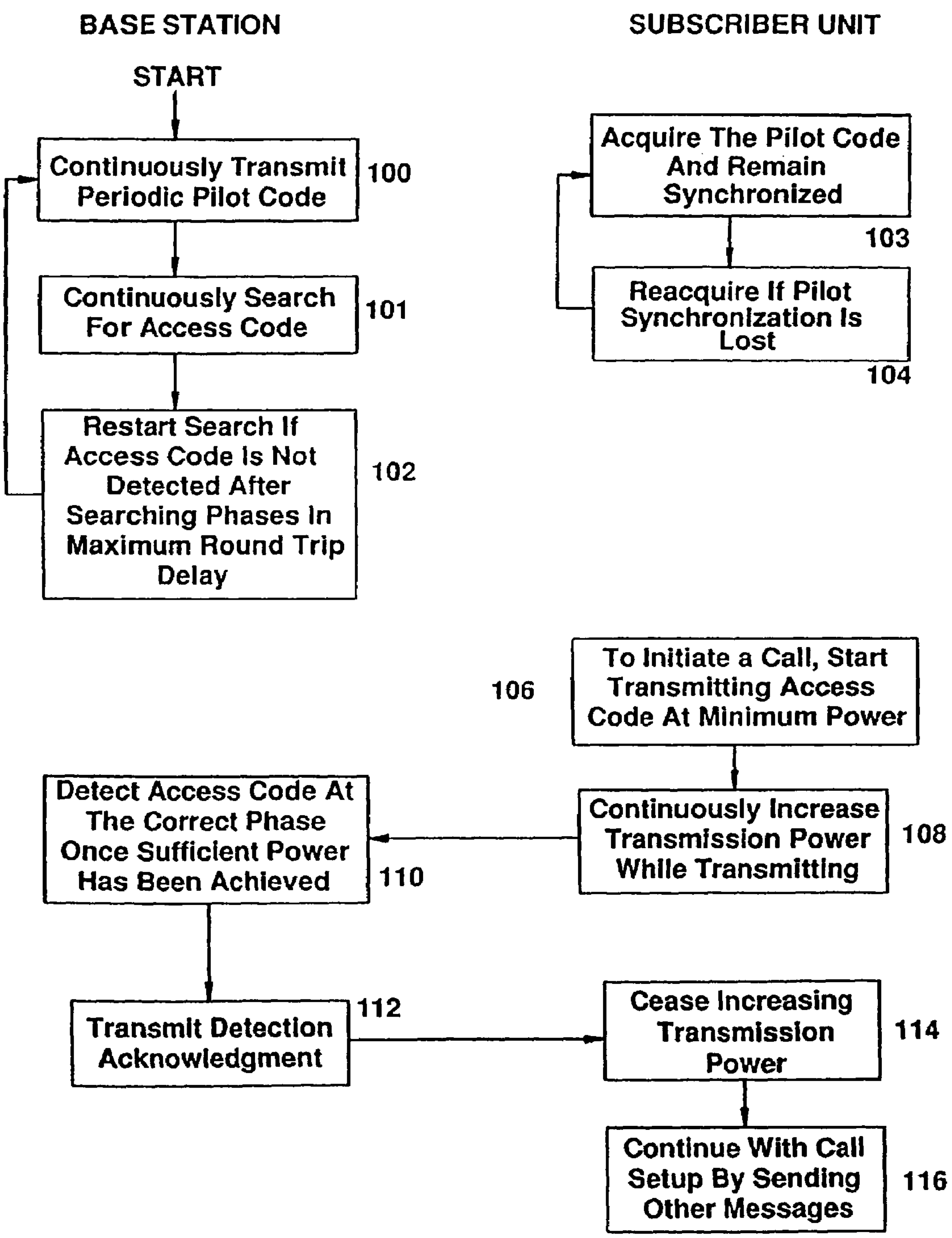

BASE STATION
SUBSCRIBER UNIT
START
Continuously Transmit Periodic Pilot Code
100
Continuously Search For Access Code
101
Restart Search If Access Code Is Not Detected After Searching Phases In Maximum Round Trip Delay
102
Acquire The Pilot Code And Remain Synchronized
103
Reacquire If Pilot Synchronization Is Lost
104
To Initiate a Call, Start Transmitting Access Code At Minimum Power
106
Continuously Increase Transmission Power While Transmitting
108
Detect Access Code At The Correct Phase Once Sufficient Power Has Been Achieved
110
Transmit Detection Acknowledgment
112
Cease Increasing Transmission Power
114
Continue With Call Setup By Sending Other Messages
116

FIG.5

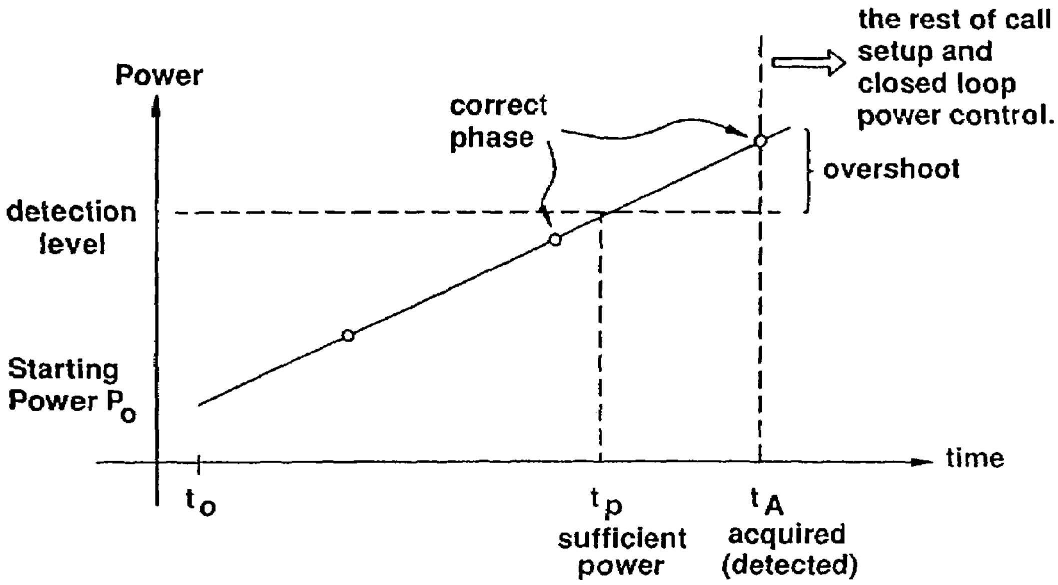

Power
correct phase
the rest of call setup and closed loop power control.
overshoot
detection level
Starting Power P_o
time
t_o
t_p sufficient power
t_A acquired (detected)

FIG.7

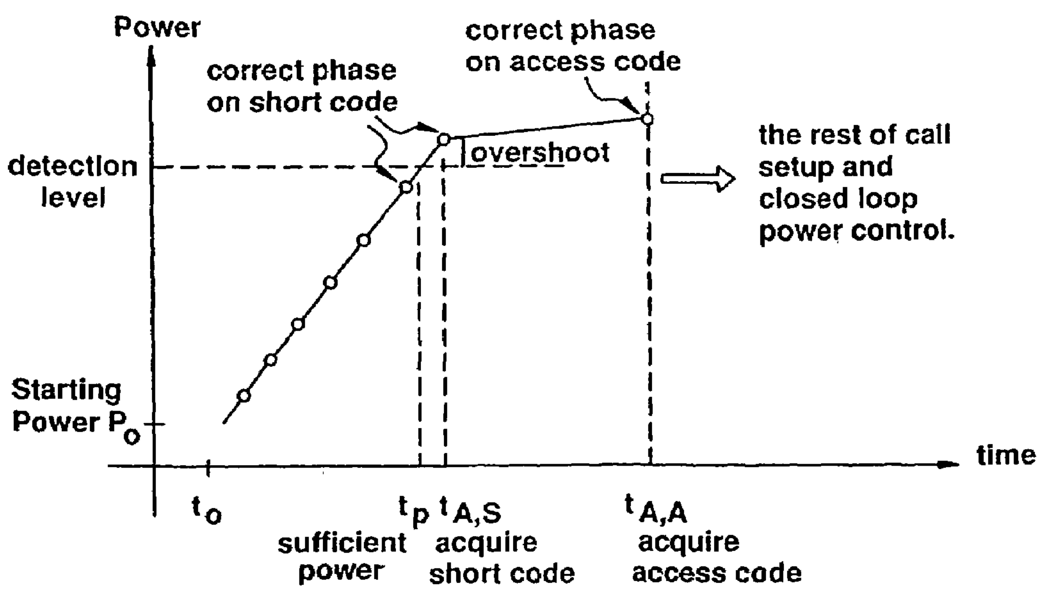

Power
correct phase on short code
correct phase on access code
overshoot
the rest of call setup and closed loop power control.
detection level
Starting Power P_o
time
t_o
t_p sufficient power
$t_{A,S}$ acquire short code
$t_{A,A}$ acquire access code

FIG.6A

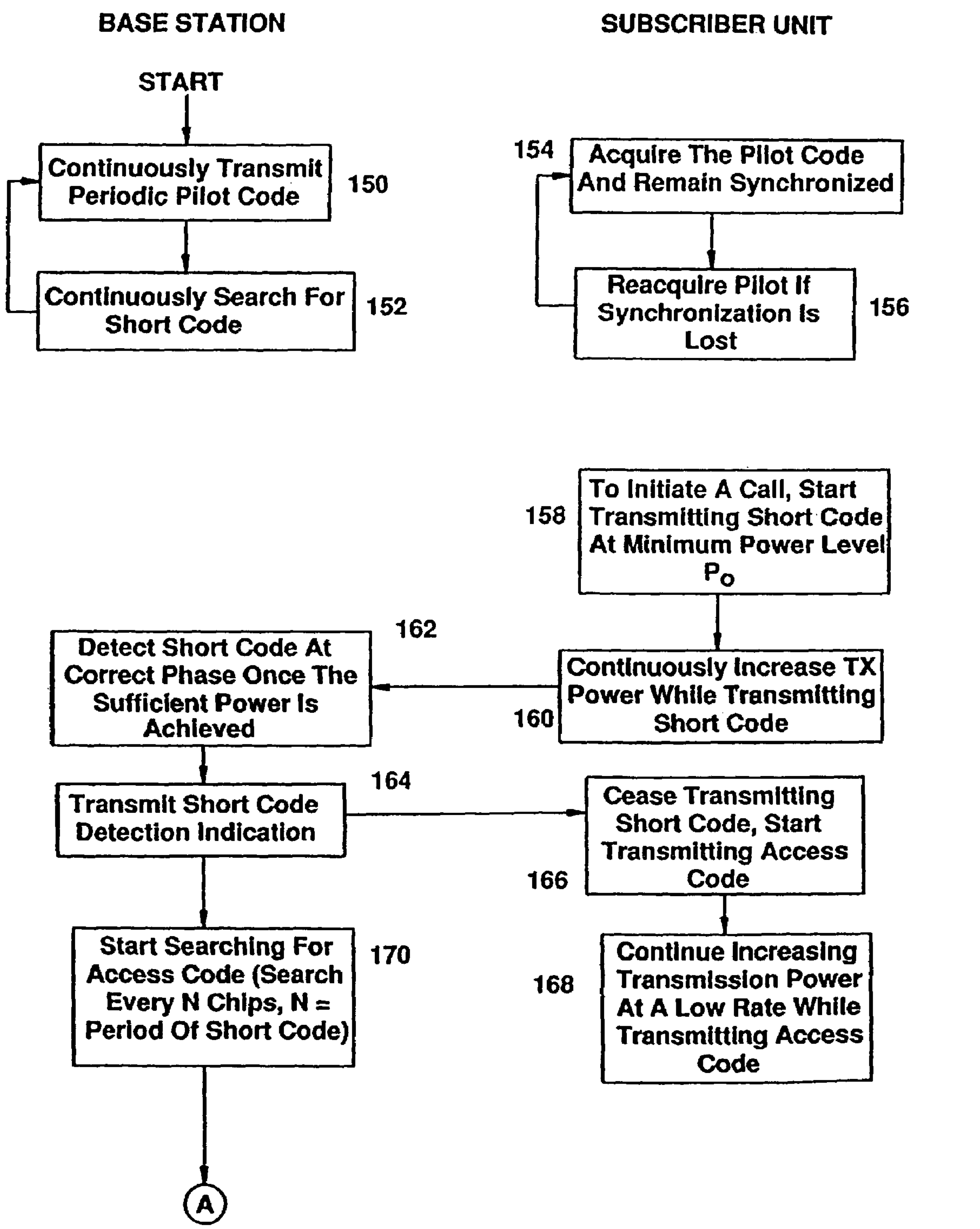

BASE STATION
SUBSCRIBER UNIT
START
Continuously Transmit Periodic Pilot Code
150
Continuously Search For Short Code
152
154
Acquire The Pilot Code And Remain Synchronized
Reacquire Pilot If Synchronization Is Lost
156
158
To Initiate A Call, Start Transmitting Short Code At Minimum Power Level P_o
162
Detect Short Code At Correct Phase Once The Sufficient Power Is Achieved
Continuously Increase TX Power While Transmitting Short Code
160
164
Transmit Short Code Detection Indication
Cease Transmitting Short Code, Start Transmitting Access Code
166
Start Searching For Access Code (Search Every N Chips, N = Period Of Short Code)
170
168
Continue Increasing Transmission Power At A Low Rate While Transmitting Access Code
A

FIG.6B

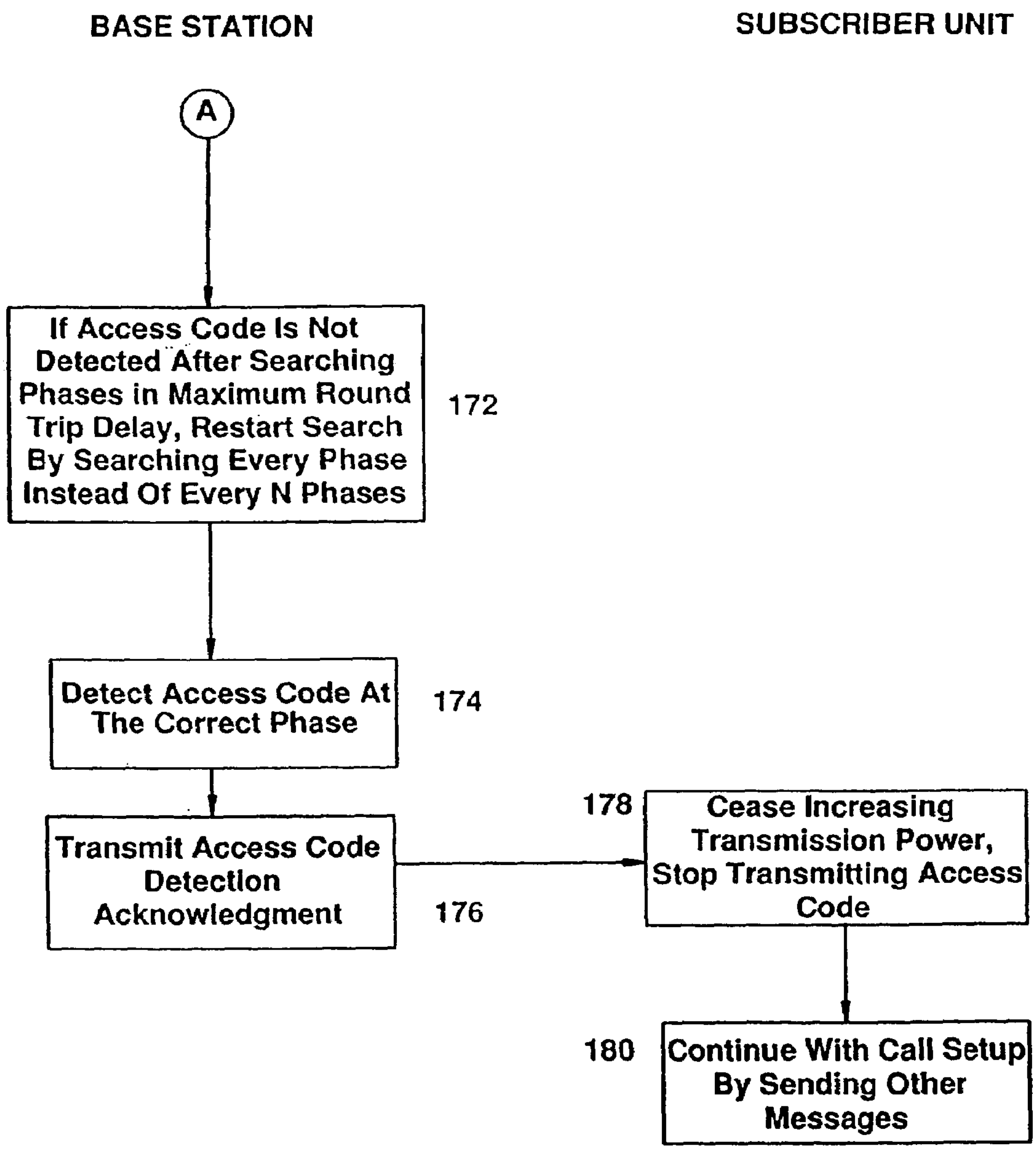

BASE STATION
SUBSCRIBER UNIT
A
If Access Code Is Not Detected After Searching Phases in Maximum Round Trip Delay, Restart Search By Searching Every Phase Instead Of Every N Phases
172
Detect Access Code At The Correct Phase
174
Transmit Access Code Detection Acknowledgment
176
178
Cease Increasing Transmission Power, Stop Transmitting Access Code
180
Continue With Call Setup By Sending Other Messages

FIG.8

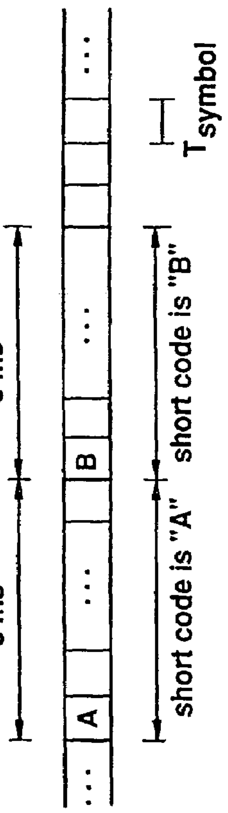

3 ms
3 ms
A
B
short code is "A"
short code is "B"
T_{symbol}

FIG.9

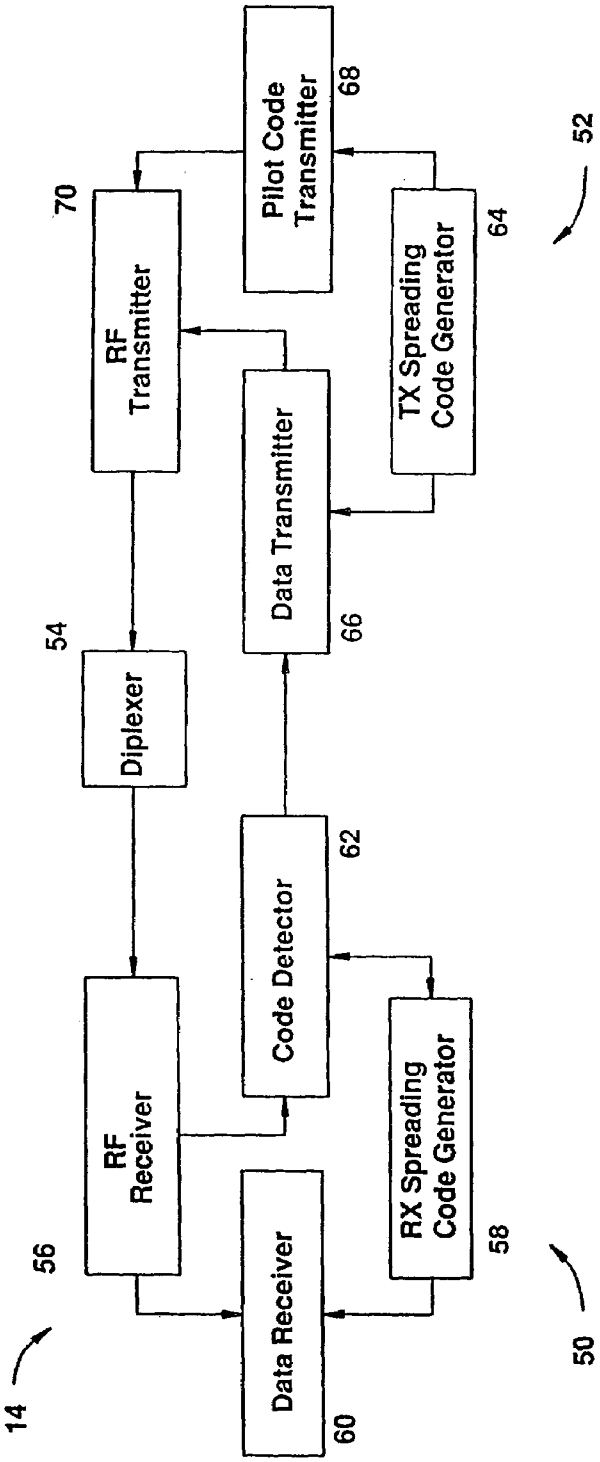
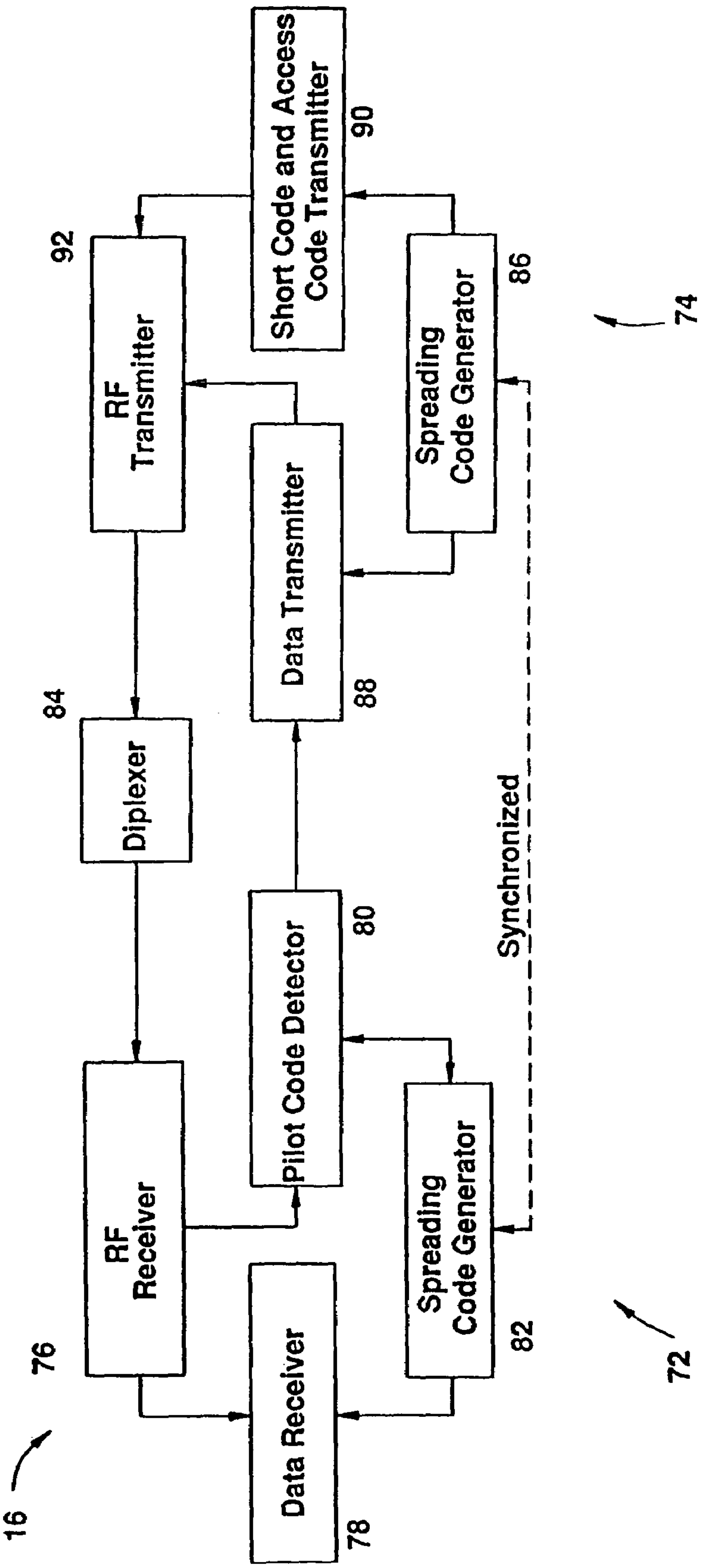

Pilot Code Transmitter
68
70
RF Transmitter
TX Spreading Code Generator
64
52
Data Transmitter
66
54
Diplexer
Code Detector
62
RF Receiver
RX Spreading Code Generator
58
56
Data Receiver
60
14
50

FIG.10



Short Code and Access Code Transmitter
90
92
RF Transmitter
Data Transmitter
88
Spreading Code Generator
86
74
84
Diplexer
Pilot Code Detector
80
Synchronized
RF Receiver
76
Spreading Code Generator
82
72
Data Receiver
78
16

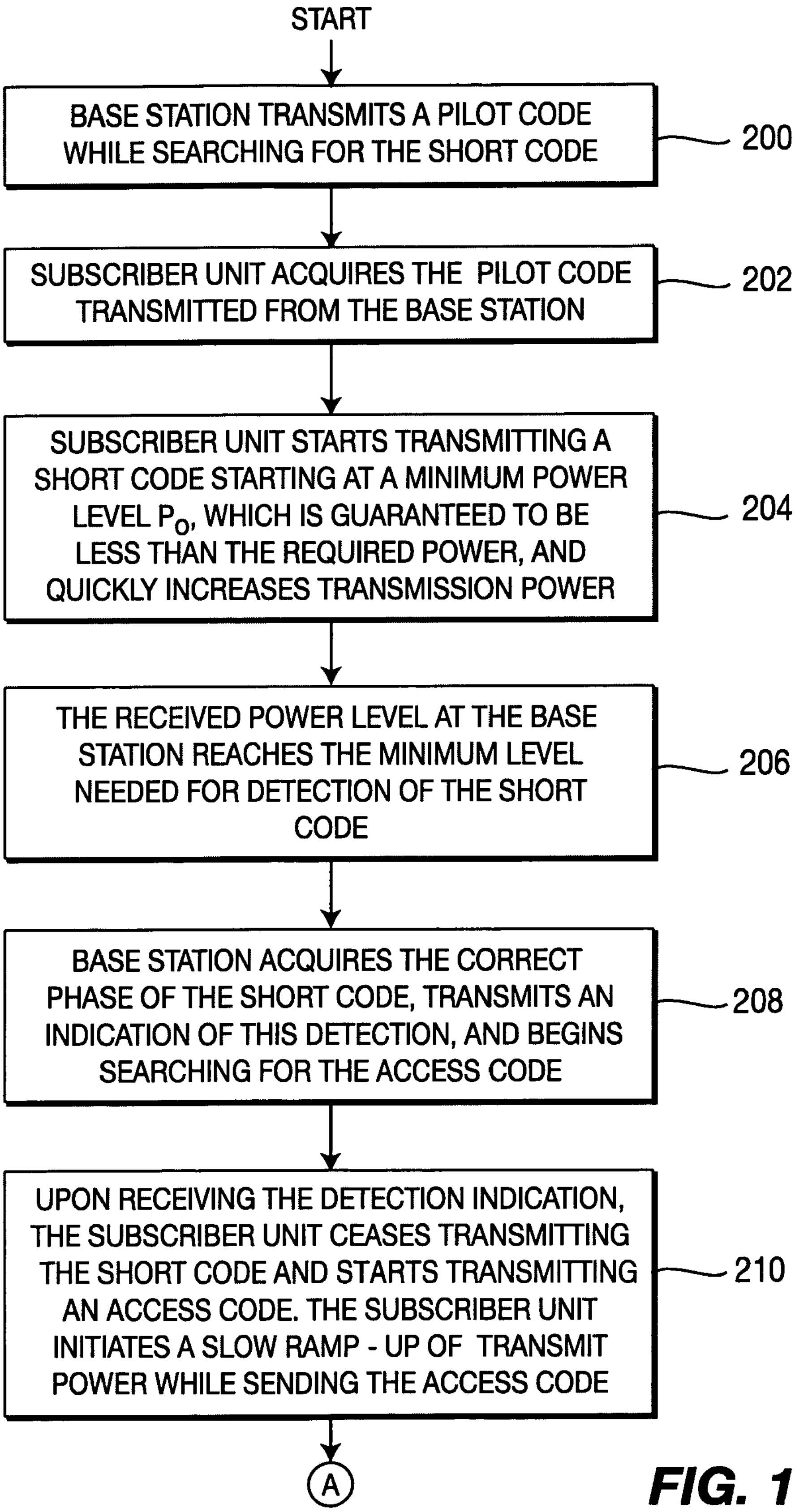

START
BASE STATION TRANSMITS A PILOT CODE WHILE SEARCHING FOR THE SHORT CODE
200
SUBSCRIBER UNIT ACQUIRES THE PILOT CODE TRANSMITTED FROM THE BASE STATION
202
SUBSCRIBER UNIT STARTS TRANSMITTING A SHORT CODE STARTING AT A MINIMUM POWER LEVEL P_0, WHICH IS GUARANTEED TO BE LESS THAN THE REQUIRED POWER, AND QUICKLY INCREASES TRANSMISSION POWER
204
THE RECEIVED POWER LEVEL AT THE BASE STATION REACHES THE MINIMUM LEVEL NEEDED FOR DETECTION OF THE SHORT CODE
206
BASE STATION ACQUIRES THE CORRECT PHASE OF THE SHORT CODE, TRANSMITS AN INDICATION OF THIS DETECTION, AND BEGINS SEARCHING FOR THE ACCESS CODE
208
UPON RECEIVING THE DETECTION INDICATION, THE SUBSCRIBER UNIT CEASES TRANSMITTING THE SHORT CODE AND STARTS TRANSMITTING AN ACCESS CODE. THE SUBSCRIBER UNIT INITIATES A SLOW RAMP - UP OF TRANSMIT POWER WHILE SENDING THE ACCESS CODE
210
A

FIG. 11A

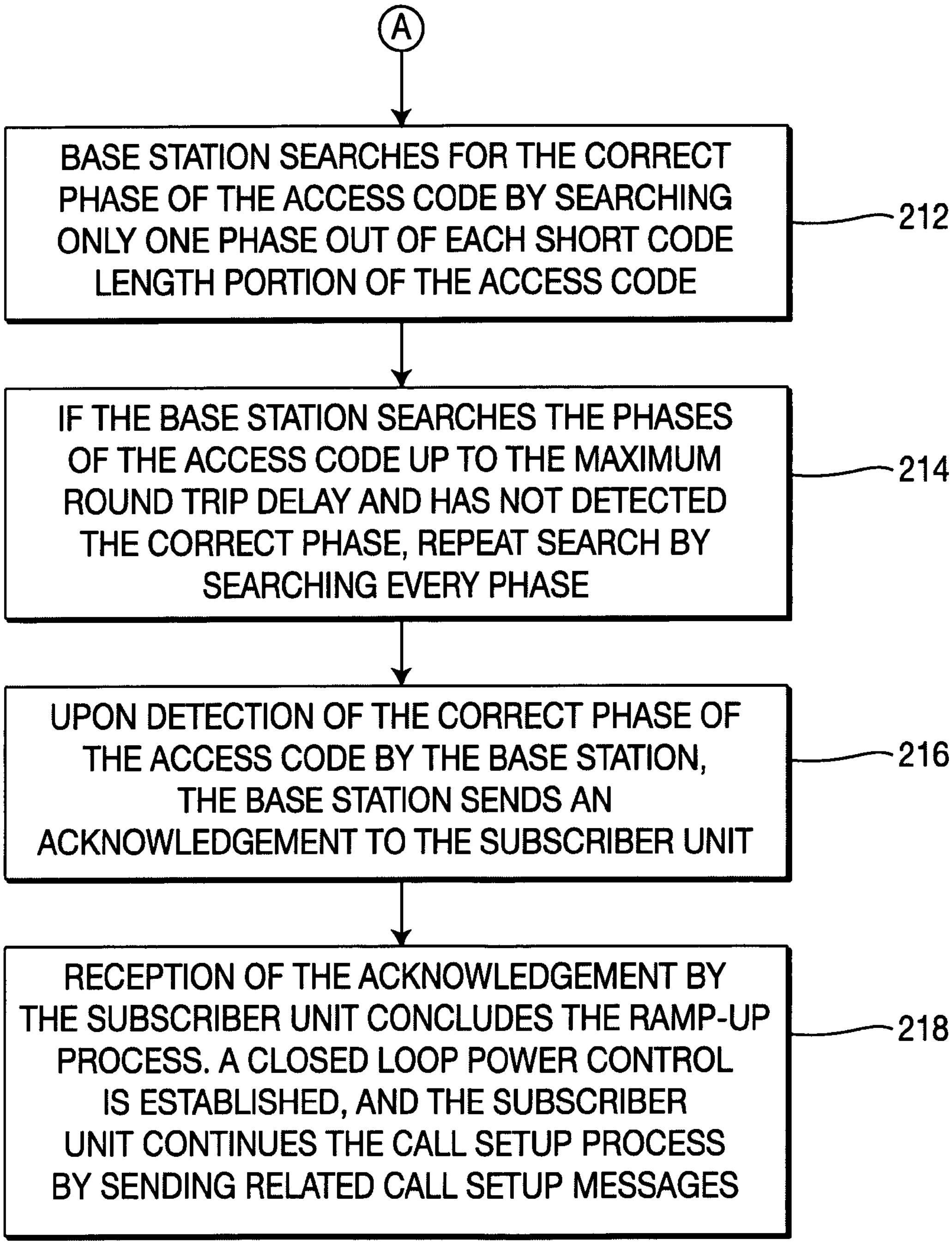

A
BASE STATION SEARCHES FOR THE CORRECT PHASE OF THE ACCESS CODE BY SEARCHING ONLY ONE PHASE OUT OF EACH SHORT CODE LENGTH PORTION OF THE ACCESS CODE
212
IF THE BASE STATION SEARCHES THE PHASES OF THE ACCESS CODE UP TO THE MAXIMUM ROUND TRIP DELAY AND HAS NOT DETECTED THE CORRECT PHASE, REPEAT SEARCH BY SEARCHING EVERY PHASE
214
UPON DETECTION OF THE CORRECT PHASE OF THE ACCESS CODE BY THE BASE STATION, THE BASE STATION SENDS AN ACKNOWLEDGEMENT TO THE SUBSCRIBER UNIT
216
RECEPTION OF THE ACKNOWLEDGEMENT BY THE SUBSCRIBER UNIT CONCLUDES THE RAMP-UP PROCESS. A CLOSED LOOP POWER CONTROL IS ESTABLISHED, AND THE SUBSCRIBER UNIT CONTINUES THE CALL SETUP PROCESS BY SENDING RELATED CALL SETUP MESSAGES
218

FIG. 11B

METHOD AND SUBSCRIBER UNIT FOR PERFORMING AN ACCESS PROCEDURE

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation of application Ser. No. 10/400,343, filed Mar. 26, 2003 now U.S. Pat. No. 6,839,567 which is a continuation of Ser. No. 10/086,320, filed Mar. 1, 2002, which issued on May 27, 2003 as U.S. Pat. No. 6,571,105; which is a continuation of application Ser. No. 09/721,034, filed Nov. 22, 2000, which issued on Dec. 10, 2002 as U.S. Pat. No. 6,493,563; which is a continuation of application Ser. No. 09/003,104, filed Jan. 6, 1998, which issued on Jan. 30, 2001 as U.S. Pat. No. 6,181,949; which is a continuation of application Ser. No. 08/670,162, filed on Jun. 27, 1996, which issued on Nov. 24, 1998 as U.S. Pat. No. 5,841,768; which applications and patents are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to CDMA communication systems. More specifically, the present invention relates to a CDMA communication system which utilizes the transmission of short codes from subscriber units to a base station to reduce the time required for the base station to detect the signal from a subscriber unit. The improved detection time allows a faster ramp-up of the initial transmit power from the subscriber units while reducing the unnecessary power overshoot.

2. Description of Related Art

The use of wireless telecommunication systems has grown dramatically in the last decade as the reliability and capacity of the systems have improved. Wireless communication systems are being utilized in a variety of applications where land line based systems are impractical or impossible to use. Applications of wireless communications include cellular phone communications, communications in remote locations, and temporary communications for disaster recovery. Wireless communication systems have also become an economically viable alternative to replacing aging telephone lines and outdated telephone equipment.

The portion of the RF spectrum available for use by wireless communication systems is a critical resource. The RF spectrum must be shared among all commercial, governmental and military applications. There is a constant desire to improve the efficiency of wireless communication systems in order to increase system capacity.

Code division multiple access (CDMA) wireless communication systems have shown particular promise in this area. Although more traditional time division multiple access (TDMA) and frequency division multiple access (FDMA) systems have improved using the latest technological advances, CDMA systems, in particular Broadband Code Division Multiple Access™ (B-CDMA™) systems, have significant advantages over TDMA and FDMA systems. This efficiency is due to the improved coding and modulation density, interference rejection and multipath tolerance of B-CDMA™ systems, as well as reuse of the same spectrum in every communication cell. The format of CDMA communication signals also makes it extremely difficult to intercept calls, thereby ensuring greater privacy for callers and providing greater immunity against fraud.

In a CDMA system, the same portion of the frequency spectrum is used for communication by all subscriber units.

Each subscriber unit's baseband data signal is multiplied by a code sequence, called the "spreading code", which has a much higher rate than the data. The ratio of the spreading code rate to the data symbol rate is called the "spreading factor" or the "processing gain". This coding results in a much wider transmission spectrum than the spectrum of the baseband data signal, hence the technique is called "spread spectrum". Subscriber units and their communications can be discriminated by assigning a unique spreading code to each communication link which is called a CDMA channel. Since all communications are sent over the same frequency band, each CDMA communication overlaps communications from other subscriber units and noise-related signals in both frequency and time.

The use of the same frequency spectrum by a plurality of subscriber units increases the efficiency of the system. However, it also causes a gradual degradation of the performance of the system as the number of users increase. Each subscriber unit detects communication signals with its unique spreading code as valid signals and all other signals are viewed as noise. The stronger the signal from a subscriber unit arrives at the base station, the more interference the base station experiences when receiving and demodulating signals from other subscriber units. Ultimately, the power from one subscriber unit may be great enough to terminate communications of other subscriber units. Accordingly, it is extremely important in wireless CDMA communication systems to control the transmission power of all subscriber units. This is best accomplished by using a closed loop power control algorithm once a communication link is established. A detailed explanation of such a closed loop algorithm is disclosed in U.S. patent application entitled Code Division Multiple Access (CDMA) System and Method filed concurrently herewith, which is incorporated by reference as if fully set forth.

The control of transmission power is particularly critical when a subscriber unit is attempting to initiate communications with a base station and a power control loop has not yet been established. Typically, the transmission power required from a subscriber unit changes continuously as a function of the propagation loss, interference from other subscribers, channel noise, fading and other channel characteristics. Therefore, a subscriber unit does not know the power level at which it should start transmitting. If the subscriber unit begins transmitting at a power level that is too high, it may interfere with the communications of other subscriber units and may even terminate the communications of other subscriber units. If the initial transmission power level is too low, the subscriber unit will not be detected by the base station and a communication link will not be established.

There are many methods for controlling transmission power in a CDMA communication system. For example, U.S. Pat. No. 5,056,109 (Gilhousen et al.) discloses a transmission power control system wherein the transmission power of the subscriber unit is based upon periodic signal measurements from both the subscriber unit and the base station. The base station transmits a pilot signal to all subscriber units which analyze the received pilot signal, estimate the power loss in the transmitted signal and adjust their transmission power accordingly. Each subscriber unit includes a non-linear loss output filter which prevents sudden increases in power which would cause interference to other subscriber units. This method is too complex to permit a base station to quickly acquire a subscriber unit while limiting the interference to other subscriber units. In addition, the propagation losses, interference and noise levels experienced in a forward link (transmission from the base

station to a subscriber unit) is often not the same as in a reverse link (transmission from a subscriber unit to the base station). Reverse link power estimates based on forward link losses are not precise.

Many other types of prior art transmission power control systems require complex control signaling between communicating units or preselected transmission values to control transmission power. These power control techniques are inflexible and often impractical to implement.

Accordingly, there is a need for an efficient method of controlling the initial ramp-up of transmission power by subscriber units in a wireless CDMA communication system.

SUMMARY OF THE INVENTION

The present invention comprises a novel method of controlling transmission power during the establishment of a channel in a CDMA communication system by utilizing the transmission of a short code from a subscriber unit to a base station during initial power ramp-up. The short code is a sequence for detection by the base station which has a much shorter period than a conventional spreading code. The ramp-up starts from a power level that is guaranteed to be lower than the required power level for detection by the base station. The subscriber unit quickly increases transmission power while repeatedly transmitting the short code until the signal is detected by the base station. Once the base station detects the short code, it sends an indication to the subscriber unit to cease increasing transmission power. The use of short codes limits power overshoot and interference to other subscriber stations and permits the base station to quickly synchronize to the spreading code used by the subscriber unit.

Accordingly, it is an object of the present invention to provide an improved technique for controlling power ramp-up during establishment of a communication channel between a CDMA subscriber unit and base station.

Other objects and advantages of the present invention will become apparent after reading the description of a presently preferred embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic overview of a code division multiple access communication system in accordance with the present invention;

FIG. **2** is a diagram showing the operating range of a base station;

FIG. **3** is a timing diagram of communication signals between a base station and a subscriber unit;

FIG. **4** is a flow diagram of the establishment of a communication channel between a base station and a subscriber unit;

FIG. **5** is a graph of the transmission power output from a subscriber unit;

FIGS. **6**A and **6**B are flow diagrams of the establishment of a communication channel between a base station and a subscriber unit in accordance with the preferred embodiment of the present invention using short codes;

FIG. **7** is a graph of the transmission power output from a subscriber unit using short codes;

FIG. **8** shows the adaptive selection of short codes;

FIG. **9** is a block diagram of a base station in accordance with the present invention;

FIG. **10** is a block diagram of the subscriber unit in accordance with the present invention; and

FIGS. **11**A and **11**B are flow diagrams of the ramp-up procedure implemented in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred embodiment will be described with reference to the drawing figures where identical numerals represent similar elements throughout.

A communication network **10** embodying the present invention is shown in FIG. **1**. The communication network **10** generally comprises one or more base stations **14**, each of which is in wireless communication with a plurality of subscriber units **16**, which may be fixed or mobile. Each subscriber unit **16** communicates with either the closest base station **14** or the base station **14** which provides the strongest communication signal. The base stations **14** also communicate with a base station controller **20**, which coordinates communications among base stations **14**. The communication network **10** may also be connected to a public switched telephone network (PSTN) **22**, wherein the base station controller **20** also coordinates communications between the base stations **14** and the PSTN **22**. Preferably, each base station **14** communicates with the base station controller **20** over a wireless link, although a land line may also be provided. A land line is particularly applicable when a base station **14** is in close proximity to the base station controller **20**.

The base station controller **20** performs several functions. Primarily, the base station controller **20** provides all of the operations, administrative and maintenance (OA&M) signaling associated with establishing and maintaining all of the wireless communications between the subscriber units **16**, the base stations **14**, and the base station controller **20**. The base station controller **20** also provides an interface between the wireless communication system **10** and the PSTN **22**. This interface includes multiplexing and demultiplexing of the communication signals that enter and leave the system **10** via the base station controller **20**. Although the wireless communication system **10** is shown employing antennas to transmit RF signals, one skilled in the art should recognize that communications may be accomplished via microwave or satellite uplinks. Additionally, the functions of the base station controller **20** may be combined with a base station **14** to form a "master base station".

Referring to FIG. **2**, the propagation of signals between a base station **14** and a plurality of subscriber units **16** is shown. A two-way communication channel (link) **18** comprises a signal transmitted **21** (Tx) from the base station **14** to the subscriber unit **16** and a signal received **23** (Rx) by the base station **14** from the subscriber unit **16**. The Tx signal **21** is transmitted from the base station **14** and is received by the subscriber unit **16** after a propagation delay Δt. Similarly, the Rx signal originates at the subscriber unit **16** and terminates at the base station **14** after a further propagation delay Δt. Accordingly, the round trip propagation delay is $2\Delta t$. In the preferred embodiment, the base station **14** has an operating range of approximately 30 kilometers. The round trip propagation delay **24** associated with a subscriber unit **16** at the maximum operating range is 200 microseconds.

It should be apparent to those of skill in the art that the establishment of a communication channel between a base station and a subscriber unit is a complex procedure involving many tasks performed by the base station and the subscriber unit which are outside the scope of the present

invention. The present invention is directed to initial power ramp-up and synchronization during the establishment of a communication channel.

Referring to FIG. **3**, the signaling between a base station **14** and a subscriber unit **16** is shown. In accordance with the present invention, the base station **14** continuously transmits a pilot code **40** to all of the subscriber units **16** located within the transmitting range of the base station **14**. The pilot code **40** is a spreading code which carries no data bits. The pilot code **40** is used for subscriber unit **16** acquisition and synchronization, as well as for determining the parameters of the adaptive matched filter used in the receiver.

The subscriber unit **16** must acquire the pilot code **40** transmitted by the base station **14** before it can receive or transmit any data. Acquisition is the process whereby the subscriber unit **16** aligns its locally generated spreading code with the received pilot code **40**. The subscriber unit **16** searches through all of the possible phases of the received pilot code **40** until it detects the correct phase, (the beginning of the pilot code **40**).

The subscriber unit **16** then synchronizes its transmit spreading code to the received pilot code **40** by aligning the beginning of its transmit spreading code to the beginning of the pilot code **40**. One implication of this receive and transmit synchronization is that the subscriber unit **16** introduces no additional delay as far as the phase of the spreading codes are concerned. Accordingly, as shown in FIG. **3**, the relative delay between the pilot code **40** transmitted from the base station **14** and the subscriber unit's transmit spreading code **42** received at the base station **14** is $2\Delta t$, which is solely due to the round trip propagation delay.

In the preferred embodiment, the pilot code is 29,877,120 chips in length and takes approximately 2 to 5 seconds to transmit, depending on the spreading factor. The length of the pilot code **40** was chosen to be a multiple of the data symbol no matter what kind of data rate or bandwidth is used. As is well known by those of skill in the art, a longer pilot code **40** has better randomness properties and the frequency response of the pilot code **40** is more uniform. Additionally, a longer pilot code **40** provides low channel cross correlation, thus increasing the capacity of the system **10** to support more subscriber units **16** with less interference. The use of a long pilot code **40** also supports a greater number of random short codes. For synchronization purposes, the pilot code **40** is chosen to have the same period as all of the other spreading codes used by the system **10**. Thus, once a subscriber unit **16** acquires the pilot code **40**, it is synchronized to all other signals transmitted from the base station **14**.

During idle periods, when a call is not in progress or pending, the subscriber unit **16** remains synchronized to the base station **14** by periodically reacquiring the pilot code **40**. This is necessary for the subscriber unit **16** to receive and demodulate any downlink transmissions, in particular paging messages which indicate incoming calls.

When a communication link is desired, the base station **14** must acquire the signal transmitted from the subscriber unit **16** before it can demodulate the data. The subscriber unit **16** must transmit an uplink signal for acquisition by the base station **14** to begin establishing the two-way communication link. A critical parameter in this procedure is the transmission power level of the subscriber unit **16**. A transmission power level that is too high can impair communications in the whole service area, whereas a transmission power level that is too low can prevent the base station **14** from detecting the uplink signal.

In a first embodiment of the present invention the subscriber unit **16** starts transmitting at a power level guaranteed to be lower than what is required and increases transmission power output until the correct power level is achieved. This avoids sudden introduction of a strong interference, hence improving system **10** capacity.

The establishment of a communication channel in accordance with the present invention and the tasks performed by the base station **14** and a subscriber unit **16** are shown in FIG. **4**. Although many subscriber units **16** may be located within the operating range of the base station **14**, reference will be made hereinafter to a single subscriber unit **16** for simplicity in explaining the operation of the present invention.

The base station **14** begins by continuously transmitting a periodic pilot code **40** to all subscriber units **16** located within the operating range of the base station **14** (step **100**). As the base station **14** transmits the pilot code **40** (step **100**), the base station **14** searches (step **101**) for an "access code' **42** transmitted by a subscriber unit **16**. The access code **42** is a known spreading code transmitted from a subscriber unit **16** to the base station **14** during initiation of communications and power ramp-up. The base station **14** must search through all possible phases (time shifts) of the access code **42** transmitted from the subscriber unit **16** in order to find the correct phase. This is called the "acquisition" or the "detection" process (step **101**). The longer the access code **42**, the longer it takes for the base station **14** to search through the phases and acquire the correct phase.

As previously explained, the relative delay between signals transmitted from the base station **14** and return signals received at the base station **14** corresponds to the round trip propagation delay $2\Delta t$. The maximum delay occurs at the maximum operating range of the base station **14**, known as the cell boundary. Accordingly, the base station **14** must search up to as many code phases as there are in the maximum round trip propagation delay, which is typically less code phases than there are in a code period.

For a data rate Rb and spreading code rate Rc, the ratio $L=Rc/Rb$ is called the spreading factor or the processing gain. In the preferred embodiment of the present invention, the cell boundary radius is 30 km, which corresponds to approximately between 1000 and 2500 code phases in the maximum round trip delay, depending on the processing gain.

If the base station **14** has not detected the access code after searching through the code phases corresponding to the maximum round trip delay the search is repeated starting from the phase of the pilot code **40** which corresponds to zero delay (step **102**).

During idle periods, the pilot code **40** from the base station **14** is received at the subscriber unit **16** which periodically synchronizes its transmit spreading code generator thereto (step **103**). If synchronization with the pilot code **40** is lost, the subscriber unit **16** reacquires the pilot code **40** and resynchronizes (step **104**).

When it is desired to initiate a communication link, the subscriber unit **16** starts transmitting the access code **42** back to the base station **14** (step **106**). The subscriber unit **16** continuously increases the transmission power while retransmitting the access code **42** (step **108**) until it receives an acknowledgment from the base station **14**. The base station **14** detects the access code **42** at the correct phase once the minimum power level for reception has been achieved (step **110**). The base station **14** subsequently transmits an access code detection acknowledgment signal (step **112**) to the subscriber unit **16**. Upon receiving the acknowl-

edgment, the subscriber unit ceases the transmission power increase (step **114**). With the power ramp-up completed, closed loop power control and call setup signaling is performed (step **116**) to establish the two-way communication link.

Although this embodiment limits subscriber unit **16** transmission power, acquisition of the subscriber unit **16** by the base station **14** in this manner may lead to unnecessary power overshoot from the subscriber unit **16**, thereby reducing the performance of the system **10**.

The transmission power output profile of the subscriber unit **16** is shown in FIG. **5**. At t_0, the subscriber unit **16** starts transmitting at the starting transmission power level P_0, which is a power level guaranteed to be less than the power level required for detection by the base station **14**. The subscriber unit **16** continually increases the transmission power level until it receives the detection indication from the base station **14**. For the base station **14** to properly detect the access code **42** from the subscriber unit **16** the access code **42** must: 1) be received at a sufficient power level; and 2) be detected at the proper phase. Accordingly, referring to FIG. **5**, although the access code **42** is at a sufficient power level for detection by the base station **14** at t_P, the base station **14** must continue searching for the correct phase of the access code **42** which occurs at t_A.

Since the subscriber unit **16** continues to increase the output transmission power level until it receives the detection indication from the base station **14**, the transmission power of the access code **42** exceeds the power level required for detection by the base station **14**. This causes unnecessary interference to all other subscriber units **16**. If the power overshoot is too large, the interference to other subscriber units **16** may be so severe as to terminate ongoing communications of other subscriber units **16**.

The rate that the subscriber unit **16** increases transmission power to avoid overshoot may be reduced, however, this results in a longer call setup time. Those of skill in the art would appreciate that adaptive ramp-up rates can also be used, yet these rates have shortcomings and will not appreciably eliminate power overshoot in all situations.

The preferred embodiment of the present invention utilizes "short codes" and a two-stage communication link establishment procedure to achieve fast power ramp-up without large power overshoots. The spreading code transmitted by the subscriber unit **16** is much shorter than the rest of the spreading codes (hence the term short code), so that the number of phases is limited and the base station **14** can quickly search through the code. The short code used for this purpose carries no data.

The tasks performed by the base station **14** and the subscriber unit **16** to establish a communication channel using short codes in accordance with the preferred embodiment of the present invention are shown in FIGS. **6**A and **6**B. During idle periods, the base station **14** periodically and continuously transmits the pilot code to all subscriber units **16** located within the operating range of the base station **14** (step **150**). The base station **14** also continuously searches for a short code transmitted by the subscriber unit **16** (step **152**). The subscriber unit **16** acquires the pilot code and synchronizes its transmit spreading code generator to the pilot code (step **154**). The subscriber unit **16** also periodically checks to ensure it is synchronized. If synchronization is lost, the subscriber unit **16** reacquires the pilot signal transmitted by the base station (step **156**).

When a communication link is desired, the subscriber unit **16** starts transmitting a short code at the minimum power level P_0 (step **158**) and continuously increases the transmission power level while retransmitting the short code (step **160**) until it receives an acknowledgment from the base station **14** that the short code has been detected by the base station **14**.

The access code in the preferred embodiment, as previously described herein, is approximately 30 million chips in length. However, the short code is much smaller. The short code can be chosen to be any length that is sufficiently short to permit quick detection. There is an advantage in choosing a short code length such that it divides the access code period evenly. For the access code described herein, the short code is preferably chosen to be 32, 64 or 128 chips in length. Alternatively, the short code may be as short as one symbol length, as will be described in detail hereinafter.

Since the start of the short code and the start of the access code are synchronized, once the base station **14** acquires the short code, the base station **14** knows that the corresponding phase of the access code is an integer multiple of N chips from the phase of the short code where N is the length of the short code. Accordingly, the base station **14** does not have to search all possible phases corresponding to the maximum round trip propagation delay.

Using the short code, the correct phase for detection by the base station **14** occurs much more frequently. When the minimum power level for reception has been achieved, the short code is quickly detected (step **162**) and the transmission power overshoot is limited. The transmission power ramp-up rate may be significantly increased without concern for a large power overshoot. In the preferred embodiment of the present invention, the power ramp-up rate using the short code is 1 dB per millisecond.

The base station **14** subsequently transmits a short code detection indication signal (step **164**) to the subscriber unit **16** which enters the second stage of the power ramp-up upon receiving this indication. In this stage, the subscriber unit **16** ceases transmitting the short code (step **166**) and starts continuously transmitting a periodic access code (step **166**). The subscriber unit **16** continues to ramp-up its transmission power while transmitting the access code, however the ramp-up rate is now much lower than the previous ramp-up rate used with the short code (step **168**). The ramp-up rate with the access code is preferably 0.05 dB per millisecond. The slow ramp-up avoids losing synchronization with the base station **14** due to small changes in channel propagation characteristics.

At this point, the base station **14** has detected the short code at the proper phase and power level (step **162**). The base station **14** must now synchronize to the access code which is the same length as all other spreading codes and much longer than the short code. Utilizing the short code, the base station **14** is able to detect the proper phase of the access code much more quickly. The base station **14** begins searching for the proper phase of the access code (step **170**). However, since the start of the access code is synchronized with the start of the short code, the base station **14** is only required to search every N chips; where N=the length of the short code. In summary, the base station **14** quickly acquires the access code of the proper phase and power level by: 1) detecting the short code; and 2) determining the proper phase of the access code by searching every N chips of the access code from the beginning of the short code.

If the proper phase of the access code has not been detected after searching the number of phases in the maximum round trip delay the base station **14** restarts the search for the access code by searching every chip instead of every N chips (step **172**). When the proper phase of the access code has been detected (step **174**) the base station **14**

transmits an access code detection acknowledgment (step **176**) to the subscriber unit **16** which ceases the transmission power increase (step **178**) upon receiving this acknowledgment. With the power ramp-up completed, closed loop power control and call setup signaling is performed (step **180**) to establish the two-way communication link.

Referring to FIG. **7**, although the starting power level P_0 is the same as in the prior embodiment, the subscriber unit **16** may ramp-up the transmission power level at a much higher rate by using a short code. The short code is quickly detected after the transmission power level surpasses the minimum detection level, thus minimizing the amount of transmission power overshoot.

Although the same short code may be reused by the subscriber unit **16**, in the preferred embodiment of the present invention the short codes are dynamically selected and updated in accordance with the following procedure. Referring to FIG. **8**, the period of the short code is equal to one symbol length and the start of each period is aligned with a symbol boundary. The short codes are generated from a regular length spreading code. A symbol length portion from the beginning of the spreading code is stored and used as the short code for the next 3 milliseconds. Every 3 milliseconds, a new symbol length portion of the spreading code replaces the old short code. Since the spreading code period is an integer multiple of 3 milliseconds, the same short codes are repeated once every period of the spreading code.

Periodic updating of the short code averages the interference created by the short code over the entire spectrum. A detailed description of the selection and updating of the short codes is outside the scope of this invention. However, such a detailed description is disclosed in the related application U.S. patent application entitled Code Division Multiple Access (CDMA) System and Method.

A block diagram of the base station **14** is shown in FIG. **9**. Briefly described, the base station **14** comprises a receiver section **50**, a transmitter section **52** and a diplexer **54**. An RF receiver **56** receives and down-converts the RF signal received from the diplexer **54**. The receive spreading code generator **58** outputs a spreading code to both the data receiver **60** and the code detector **62**. In the data receiver **60**, the spreading code is correlated with the baseband signal to extract the data signal which is forwarded for further processing. The received baseband signal is also forwarded to the code detector **62** which detects the access code or the short code from the subscriber unit **16** and adjusts the timing of the spreading code generator **58** to establish a communication channel **18**.

In the transmitter section **52** of the base station **14**, the transmit spreading code generator **64** outputs a spreading code to the data transmitter **66** and the pilot code transmitter **68**. The pilot code transmitter **68** continuously transmits the periodic pilot code. The data transmitter **66** transmits the short code detect indication and access code detect acknowledgment after the code detector **62** has detected the short code or the access code respectively. The data transmitter also sends other message and data signals. The signals from the data transmitter **66** and the pilot code transmitter **68** are combined and up-converted by the RF transmitter **70** for transmission to the subscriber units **16**.

A block diagram of the subscriber unit **16** is shown in FIG. **10**. Briefly described, the subscriber unit **16** comprises a receiver section **72**, a transmitter section **74** and a diplexer **84**. An RF receiver **76** receives and down-converts the RF signal received from the diplexer **84**. A pilot code detector **80** correlates the spreading code with the baseband signal to acquire the pilot code transmitted by the base station **14**. In this manner, the pilot code detector **80** maintains synchronization with the pilot code. The receiver spreading code generator **82** generates and outputs a spreading code to the data receiver **78** and the pilot code detector **80**. The data receiver **78** correlates the spreading code with the baseband signal to process the short code detect indication and the access code detect acknowledgment transmitted by the base station **14**.

The transmitter section **74** comprises a spreading code generator **86** which generates and outputs spreading codes to a data transmitter **88** and a short code and access code transmitter **90**. The short code and access code transmitter **90** transmits these codes at different stages of the power ramp-up procedure as hereinbefore described. The signals output by the data transmitter **88** and the short code and access code transmitter **90** are combined and up-converted by the RF transmitter **92** for transmission to the base station **14**. The timing of the receiver spreading code generator **82** is adjusted by the pilot code detector **80** through the acquisition process. The receiver and transmitter spreading code generators **82**, **86** are also synchronized.

An overview of the ramp-up procedure in accordance with the preferred current invention is summarized in FIGS. **11**A and **11**B. The base station **14** transmits a pilot code while searching for the short code (step **200**). The subscriber unit **16** acquires the pilot code transmitted from the base station **14** (step **202**), starts transmitting a short code starting at a minimum power level P_0 which is guaranteed to be less than the required power, and quickly increases transmission power (step **204**). Once the received power level at the base station **14** reaches the minimum level needed for detection of the short code (step **206**) the base station **14** acquires the correct phase of the short code, transmits an indication of this detection, and begins searching for the access code (step **208**). Upon receiving the detection indication, the subscriber unit **16** ceases transmitting the short code and starts transmitting an access code. The subscriber unit **16** initiates a slow ramp-up of transmit power while sending the access code (step **210**). The base station **14** searches for the correct phase of the access code by searching only one phase out of each short code length portion of the access code (step **212**). If the base station **14** searches the phases of the access code up to the maximum round trip delay and has not detected the correct phase, the search is repeated by searching every phase (step **214**). Upon detection of the correct phase of the access code by the base station **14**, the base station **14** sends an acknowledgment to the subscriber unit **16** (step **216**). Reception of the acknowledgment by the subscriber unit **16** concludes the ramp-up process. A closed loop power control is established, and the subscriber unit **16** continues the call setup process by sending related call setup messages (step **218**).

Although the invention has been described in part by making detailed reference to the preferred embodiment, such detail is intended to be instructive rather than restrictive. It will be appreciated by those skilled in the art that many variations may be made in the structure and mode of operation without departing from the spirit and scope of the invention as disclosed in the teachings herein.

What is claimed is:

1. A method for performing power control in a wireless code division multiple access communication system, the method comprising:

transmitting dynamically selected code signals at increasing power levels until an acknowledgement is received indicating that one of said dynamically selected code

signals was detected, wherein the transmitted dynamically selected code signals carry no data; and

in response to detecting the acknowledgment, transmitting an access signal wherein the access signal is associated with the dynamically selected code signals and each of the dynamically selected code signals are shorter than the access signal.

2. A wireless code division multiple access subscriber unit, the subscriber unit comprising:

a transmitter configured such that a first code is transmitted at an initial power level wherein the first code is of a first code type and the transmitter further configured to repeatedly transmit dynamically selected codes of said first code type at increasing power levels wherein the transmitted codes of said first code type carry no data;

a receiver configured such that an acknowledgement is detected indicating a code of said first type was received; and

the transmitter configured such that in response to detecting the acknowledgement, a signal having a second code is transmitted to access a communication channel wherein the second code is associated with the first code.

3. A wireless code division multiple access base station, the base station comprising:

a receiver configured such that a code of a first code type is received, the received code carrying no data and being repeatedly transmitted at increasing power levels;

a transmitter configured such that an acknowledgement is transmitted indicating a code of said first type was received; and

the receiver configured such that a signal having a second code is received as part of an access procedure wherein the second code is associated with the first code.

4. A method for transmitting a communication in a wireless code division multiple access communication system, the method comprising:

repeatedly transmitting portions of the communication without a remainder of the communication wherein each subsequently transmitted portion is transmitted at an increased power level with respect to a prior transmitted portion, the transmitted portions not including any data;

detecting an acknowledgement indicating one of the transmitted portions was received;

transmitting the remainder of the communication in response to detecting the acknowledgement as part of an access procedure; and

wherein each of the portions include a code sequence.

5. A wireless code division multiple access subscriber unit, the subscriber unit comprising:

a transmitter configured such that portions of a communication are transmitted without a remainder of the communication wherein each subsequently transmitted portion is transmitted at an increased power level with respect to a prior transmitted portion, the portions not carrying any data;

a receiver configured such that an acknowledgement is detected indicating the transmitted portion was received; and

the transmitter configured such that the remainder of the communication is transmitted in response to detecting the acknowledgement wherein each of the portions include a code sequence.

6. A wireless code division multiple access base station, the base station comprising:

a receiver configured such that a portion of a communication is received without a remainder of the communication, the portion including no data;

a transmitter configured such that an acknowledgement is transmitted indicating the portion was received;

the receiver configured such that a remainder of the communication is received as part of an access procedure; and

wherein each of the portions include a code sequence.

7. A method for use in a code division multiple access subscriber unit for establishing communications between said subscriber unit and a base station, said method comprising:

transmitting a plurality of different codes by said subscriber unit to said base station wherein each different code is transmitted at increasing power levels;

receiving an acknowledgement by said subscriber unit from said base station and ceasing transmitting the plurality of different codes, said acknowledgement indicating to said subscriber unit that said base station has received at least one of said different codes; and

transmitting, in response to receipt of said acknowledgement, an access signal to facilitate communication initialization between said subscriber unit and said base station, said access signal as transmitted by said subscriber unit and said different codes as transmitted by said subscriber unit each being a function of a same code.

8. The method of claim **7** wherein each different code is sequentially transmitted at increasing power levels.

9. The method of claim **8** wherein the transmitting of the plurality of different codes ceases based on receipt of said acknowledgement.

10. The method of claim **7** wherein the transmitting of the plurality of different codes ceases based on receipt of said acknowledgement.

11. The method of claim **7** wherein said different codes have a bit length less than said access signal.

12. The method of claim **7** wherein said same code comprises a spreading code.

13. The method of claim **12** wherein said different codes as transmitted by said subscriber unit comprise a portion of said spreading code, and wherein said access signal as transmitted by said subscriber unit comprises at least a portion of said spreading code.

14. The method of claim **7** wherein said access signal is transmitted at a power level related to a last power level of said transmitting of said different codes.

15. The method of claim **14** wherein said power level related to said last power level of said transmitting said different codes is an increased power level with respect to said last power level of said transmitting said different codes.

16. The method of claim **7** wherein said transmitting said different codes comprises transmitting a first plurality of different codes derived from a first code before transmitting a second plurality of different codes derived from a second code different than the first code.

17. A method for establishing communications between a subscriber unit and a base station in a code division multiple access communications system, said method comprising:

transmitting less than a complete initialization code sequence from the subscriber unit to the base station at a first power level;

subsequently transmitting less than a complete initialization code sequence at an increased power level;

repeating said subsequently transmitting until an acknowledgement is received by said subscriber unit from said base station; and

transmitting, in response to receipt of said acknowledgement, enough of the initialization code sequence to facilitate communication initialization between said subscriber unit and said base station at a power level related to a last power level of said transmitting of said less than said complete initialization code sequence.

18. The method of claim **17** wherein the less than a complete initialization code sequence is dynamically selected for each subsequent transmission.

19. The method of claim **17** wherein the initialization code sequence includes a spreading code.

20. The method of claim **17** wherein the subsequently transmitted less than a complete initialization code sequence includes different portions of said complete initialization code sequence for at least one of each subsequent transmission.

21. A method for performing an access procedure in a code division multiple access subscriber unit for establishing communications between said subscriber unit and a base station, said method comprising:

transmitting a first code to be used by a base station in establishing communication between said base station and said subscriber unit at a first power level, said first code not providing data of said subscriber unit;

subsequently transmitting, with respect to said first code a same or a different code, at increasing power levels until an acknowledgement is received by the subscriber unit, reception of said acknowledgement by said subscriber unit indicating to said subscriber unit that the base station has detected transmission by the subscriber unit; and

transmitting, in response to receipt of said acknowledgement, a signal by said subscriber unit as part of the access procedure wherein the signal includes a second code that is associated with the same or different code.

22. The method of claim **21** wherein said same or different code is dynamically selected.

23. The method of claim **21** wherein said same or different code has a shorter bit length than the signal transmitted as part of the access procedure.

24. The method of claim **21** wherein said same or different code and said signal transmitted as part of the access procedure are a function of a single code.

25. The method of claim **21** wherein said single code includes a spreading code.

26. A method performed by a code division multiple access subscriber unit for establishing communications between the subscriber unit and a base station, the method comprising:

repeatedly transmitting codes of a first type until the subscriber unit receives an acknowledgement signal from the base station, each transmission of a code of the first type being at an increased power level with respect to a prior transmission of a code of the first type;

upon receiving the acknowledgement signal from the base station, transmitting a code of a second type,

wherein, the acknowledgement signal is an indication to the subscriber unit that the base station has received a code of the first type, and

wherein the subscriber unit sends data to the base station only after the base station has received a code of the first type.

27. The method of claim **26** wherein the code of the first type and the code of the second type are derived from a same code sequence.

28. The method of claim **27** wherein the same code sequence includes a spreading code.

29. The method of claim **26** wherein the code of the first type has a shorter bit length than the code of the second type.

30. A method performed by a code division multiple access subscriber unit for establishing communications between the subscriber unit and a base station, the method comprising:

(a) transmitting a code of a first type, wherein the code of the first type does not include data of the subscriber unit;

(b) determining if the subscriber unit has received an acknowledgement signal from the base station, the acknowledgement signal being an indication to the subscriber unit that the base station has received a code of the first type;

(c) repeating (a) at increasing power levels until the subscriber unit has received the acknowledgement signal; and

(d) transmitting a code of a second type after it is determined that the subscriber unit has received the acknowledgement signal.

31. The method of claim **30** wherein said code of a first type is a dynamically selected code associated with said code of a second type.

32. The method of claim **30** wherein said code of a first type is shorter than said code of a second type.

33. The method of claim **30** wherein said code of a first type carries no data.

34. A method for use in a code division multiple access subscriber unit for establishing communications between said subscriber unit and a base station, said method comprising:

(a) transmitting a first one of a plurality of different codes by said subscriber unit to said base station;

(b) if an acknowledgement is not received, transmitting another one of the plurality of different codes by said subscriber unit to said base station;

(c) repeating step (b) until an acknowledgement is received by said subscriber unit from said base station, said acknowledgement indicating to said subscriber unit that said base station has received at least one of said different codes; and

(d) transmitting, in response to receipt of said acknowledgement, an access signal to facilitate communication initialization between said subscriber unit and said base station, said access signal as transmitted by said subscriber unit and said different codes as transmitted by said subscriber unit each being a function of a same code.

35. The method of claim **34** wherein the transmitting of the plurality of different codes ceases based on receipt of said acknowledgement.

36. The method of claim **34** wherein the same code includes a spreading code.

37. The method of claim **34** wherein each of the plurality of different codes has a bit length less than said access signal.

38. A subscriber unit capable of establishing communications, said subscriber unit comprising:

a code generator for producing a plurality of different codes;

a transmitter for transmitting said produced plurality of different codes, wherein each different code is transmitted at increasing power levels;

a receiver for receiving an acknowledgement, said acknowledgement indicating that at least one of said different codes was received; and

wherein said code generator is operable in response to receipt of said acknowledgment by said receiver to produce an access signal and said transmitter transmits said access signal to facilitate communication initialization by said subscriber unit, said access signal and said different codes each being a function of a same code.

39. The subscriber unit of claim **38** wherein the transmitter sequentially transmits each different code at increasing power levels.

40. The subscriber unit of claim **38** wherein said different codes have a bit length less than said access signal.

41. The subscriber unit of claim **38** wherein said same code comprises a spreading code.

42. The subscriber unit of claim **41** wherein said different codes as transmitted by said subscriber unit comprise a portion of said spreading code, and wherein said access signal as transmitted by said subscriber unit comprises at least a portion of said spreading code.

43. The subscriber unit of claim **38** wherein said access signal is transmitted at a power level related to a last power level of said transmitting of said different codes.

44. The subscriber unit of claim **43** wherein said power level related to said last power level of said transmitting said different codes is an increased power level with respect to said last power level of said transmitting said different codes.

45. The subscriber unit of claim **38** wherein said transmitting said different codes comprises transmitting a first plurality of different codes derived from a first code before transmitting a second plurality of different codes derived from a second code different than the first code.

46. A subscriber unit operable to perform an access procedure in a code division multiple access system for establishing communications between said subscriber unit and a base station, said subscriber unit comprising:

a transmitter; and

a processor configured to control said transmitter to transmit a first code to be used by a base station in establishing communication between said base station and said subscriber unit at a first power level, said first code not providing data of said subscriber unit, wherein said processor is further configured to control said transmitter to subsequently transmit, with respect to said first code a same or a different code, at increasing power levels until an acknowledgement is received by the subscriber unit, reception of said acknowledgement by said subscriber unit indicating to said subscriber unit that the base station has detected transmission by the subscriber unit, and said processor is further configured to control said transmitter to transmit, in response to receipt of said acknowledgement, a signal by said subscriber unit as part of the access procedure wherein the signal includes a second code that is associated with the same or different code.

47. The subscriber unit of claim **46** wherein the processor is configured such that said same or a different code is dynamically selected.

48. The subscriber unit of claim **46** wherein said same or different code has a shorter bit length than the signal transmitted as part of the access procedure.

49. The subscriber unit of claim **46** wherein said same or different code and said signal transmitted as part of the access procedure are a function of a single code.

50. The subscriber unit of claim **49** wherein said single code includes a spreading code.

51. A subscriber unit operable to perform an access procedure for establishing communications between the subscriber unit and a base station, the subscriber unit comprising:

a transmitter configured to repeatedly transmit codes of a first type wherein each transmission of a code of the first type is transmitted at an increased power level with respect to a prior transmission of a code of the first type;

a receiver configured to receive an acknowledgement from the base station wherein the acknowledgement signal is an indication to the subscriber unit that the base station has received a code of the first type;

the transmitter further configured to transmit a code of a second type to said base station upon receipt by the receiver of said acknowledgement, and

wherein the code of a second type includes data.

52. The subscriber unit of claim **51** wherein the transmitter is configured such that the code of the first type and the code of the second type are derived from a same code sequence.

53. The subscriber unit of claim **52** wherein the same code sequence includes a spreading code.

54. The subscriber unit of claim **51** wherein the code of the first type has a shorter bit length than the code of the second type.

55. A subscriber unit operable to perform an access procedure for establishing communications, the subscriber unit comprising:

a transmitter configured to receive a code of a first type and to transmit the received code of the first type, wherein the transmitted code of the first type does not include data of the subscriber unit;

a receiver configured to receive an acknowledgement signal, the acknowledgement signal being an indication to the subscriber unit that a code of the first type was received;

the transmitter further configured to repeatedly receive a code of the first type and to transmit each received code of the first type until the receiver receives the acknowledgement signal; wherein the received transmitted codes of a first type are transmitted at increasing power levels until the receiver has received the acknowledgement signal; and

the transmitter, in response to the receiver receiving an acknowledgement, further configured to receive a code of a second type and to transmit the code of the second type.

56. The subscriber unit of claim **55** wherein the transmitter is configured such that said codes of a first type are dynamically selected codes associated with said code of a second type.

57. The subscriber unit of claim **55** wherein each of the received transmitted codes of a first type is shorter than said code of a second type.

58. The subscriber unit of claim **55** wherein said received transmitted codes of a first type carry no data.

59. A subscriber unit for performing an access procedure for establishing communications between said subscriber unit and a base station, said subscriber unit comprising:

a processor configured to control a transmitter such that the transmitter transmits a first one of a plurality of different codes by said subscriber unit to said base station;

a receiver configured to receive an acknowledgement wherein if said acknowledgement is not received, the processor configured to control the transmitter such that the transmitter transmits another one of the plurality of different codes by said subscriber unit to said base station;

the processor configured to control said transmitter such that said transmitter repeats the transmitting of another one of the plurality of different codes until said acknowledgement is received by said subscriber unit from said base station, said acknowledgement indicating to said subscriber unit that said base station has received at least one of said different codes; and

said processor configured to control the transmitter such that the transmitter transmits, in response to receipt of said acknowledgement, an access signal to facilitate communication initialization between said subscriber, unit and said base station, said access signal as transmitted by said subscriber unit and said different codes as transmitted by said subscriber unit each being a function of a same code.

60. The subscriber unit of claim **59** wherein the processor is configured to control said transmitter such that the transmitting of the plurality of different codes ceases based on receipt of said acknowledgement.

61. The subscriber unit of claim **59** wherein the same code includes a spreading code.

62. The subscriber unit of claim **59** wherein each of the plurality of different codes has a bit length less than said access signal.

63. A subscriber unit for performing an access procedure for establishing communications between a subscriber unit and a base station in a code division multiple access communications system, said subscriber unit comprising:

a transmitting arrangement configured to control a transmitter such that said transmitter transmits less than a complete initialization code sequence from the subscriber unit to the base station at a first power level;

the transmitting arrangement further configured to subsequently transmit less than a complete initialization code sequence at an increased power level and configured to repeat said subsequent transmitting until an acknowledgement is received by a receiver of said subscriber unit from said base station; and

the transmitting arrangement further configured to transmit, in response to receipt of said acknowledgement, enough of the initialization code sequence to facilitate communication initialization between said subscriber unit and said base station at a power level related to a last power level of said transmitting of said less than said complete initialization code sequence.

64. The subscriber unit of claim **63** wherein the transmitting arrangement is configured such that the less than a complete initialization code sequence is dynamically selected for each subsequent transmission.

65. The subscriber unit of claim **63** wherein the initialization code sequence includes a spreading code.

66. The subscriber unit of claim **63** wherein the subsequently transmitted less than a complete initialization code sequence includes different portions of said complete initialization code sequence for at least one of each subsequent transmission.

* * * * *

EXHIBIT B

US006674791B2

(12) United States Patent
Lomp et al.

(10) Patent No.: US 6,674,791 B2
(45) Date of Patent: *Jan. 6, 2004

(54) **AUTOMATIC POWER CONTROL SYSTEM FOR A CODE DIVISION MULTIPLE ACCESS (CDMA) COMMUNICATIONS SYSTEM**

(75) Inventors: **Gary Lomp**, Centerport, NY (US); **Fatih Ozluturk**, Port Washington, NY (US); **John Kowalski**, Hempstead, NY (US)

(73) Assignee: **InterDigital Technology Corporation**, Wilmington, DE (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 14 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **10/083,791**

(22) Filed: **Feb. 27, 2002**

(65) **Prior Publication Data**

US 2002/0118729 A1 Aug. 29, 2002

Related U.S. Application Data

(63) Continuation of application No. 09/833,285, filed on Apr. 12, 2001, which is a continuation of application No. 09/406,162, filed on Sep. 27, 1999, now abandoned, which is a continuation of application No. 08/669,770, filed on Jun. 27, 1996, now Pat. No. 5,991,329.

(60) Provisional application No. 60/000,775, filed on Jun. 30, 1995.

(51) **Int. Cl.**[7] **H04B 1/69**

(52) **U.S. Cl.** **375/146**; 375/130; 370/335; 455/522

(58) **Field of Search** 375/130, 295, 375/358; 370/335, 342; 455/69, 522

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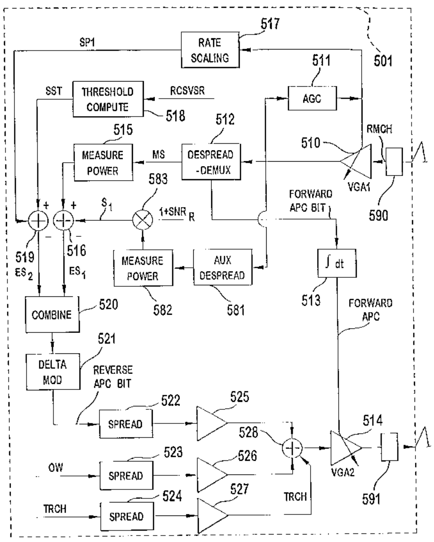
Primary Examiner—Temesghen Ghebretinsae
(74) *Attorney, Agent, or Firm*—Volpe and Koenig, P.C.

(57) **ABSTRACT**

A subscriber unit (SU) transmitter transmits signals over global and assigned channels to a base station which are initialized at an initial power level and adjusted to a controlled power level in advance of transmitting a communication data signal on an assigned channel to the base station. The power level of the SU transmitter is controlled to adjust the SU transmitter power level in response to power control signals received from the base station. The SU transmitter power level is monitored in advance of transmitting a communication data signal on an assigned channel to the base station. The transmitter is controlled such that transmission of a communication data signal on an assigned channel is blocked if a predetermined power limit is reached before commencing transmission of the communication data signal on the assigned channel.

12 Claims, 8 Drawing Sheets



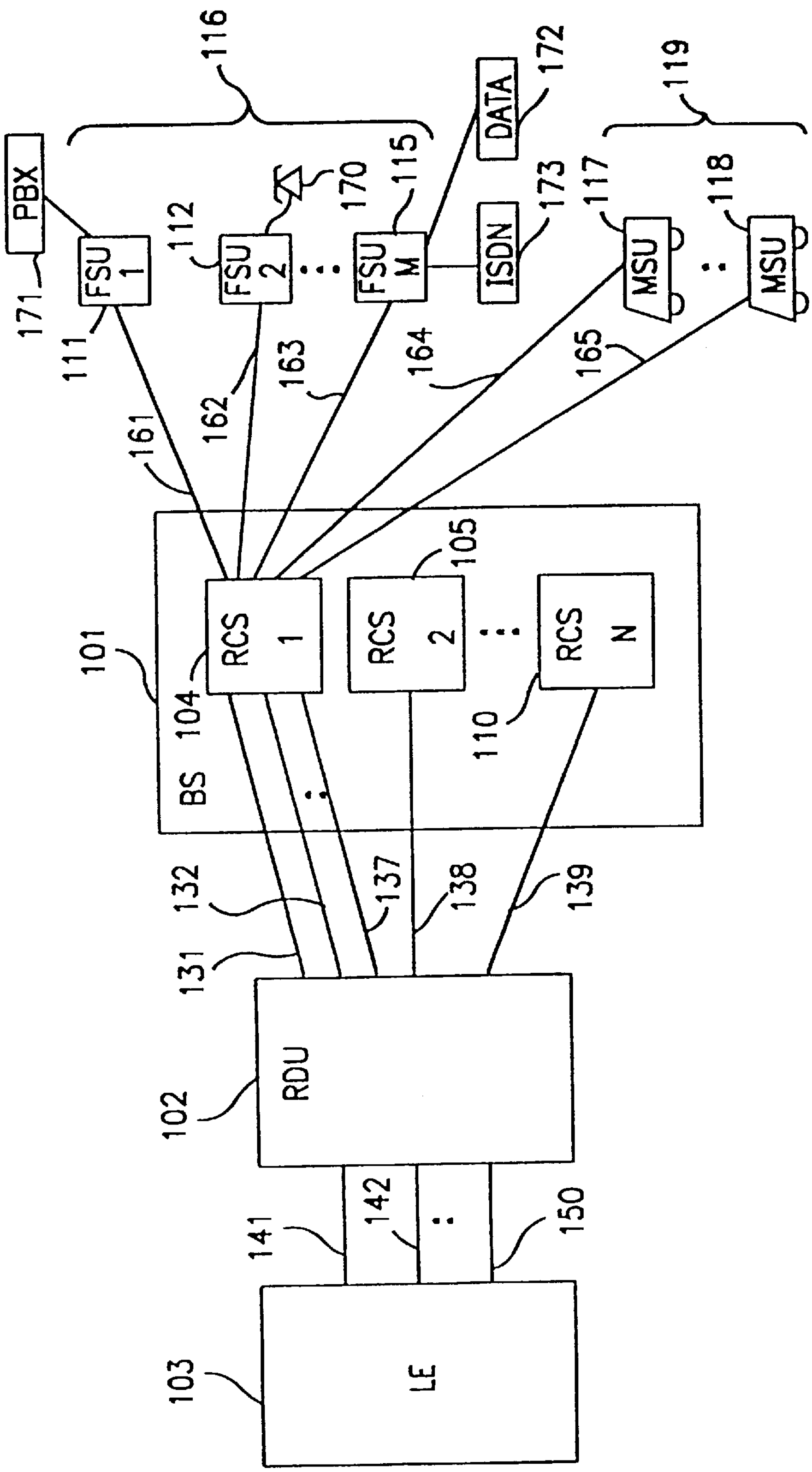

PBX
FSU 1
FSU 2
FSU M
ISDN
DATA
MSU
MSU
RCS 1
RCS 2
RCS N
BS
RDU
LE
101
102
103
104
105
110
111
112
115
116
117
118
119
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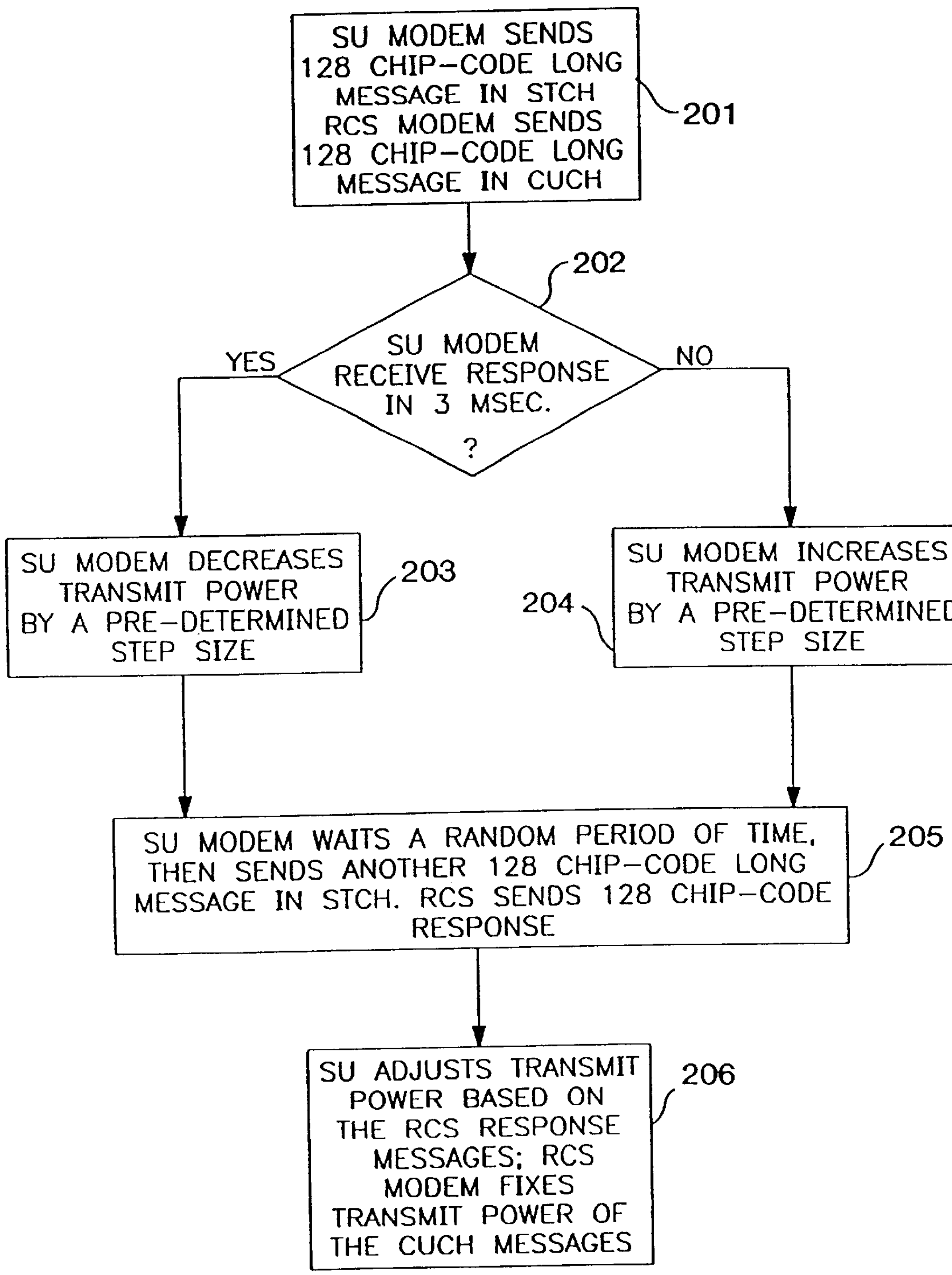
FIG. 1



SU MODEM SENDS 128 CHIP-CODE LONG MESSAGE IN STCH RCS MODEM SENDS 128 CHIP-CODE LONG MESSAGE IN CUCH
201
202
SU MODEM RECEIVE RESPONSE IN 3 MSEC. ?
YES
NO
SU MODEM DECREASES TRANSMIT POWER BY A PRE-DETERMINED STEP SIZE
203
204
SU MODEM INCREASES TRANSMIT POWER BY A PRE-DETERMINED STEP SIZE
SU MODEM WAITS A RANDOM PERIOD OF TIME, THEN SENDS ANOTHER 128 CHIP-CODE LONG MESSAGE IN STCH. RCS SENDS 128 CHIP-CODE RESPONSE
205
SU ADJUSTS TRANSMIT POWER BASED ON THE RCS RESPONSE MESSAGES; RCS MODEM FIXES TRANSMIT POWER OF THE CUCH MESSAGES
206

FIG. 2

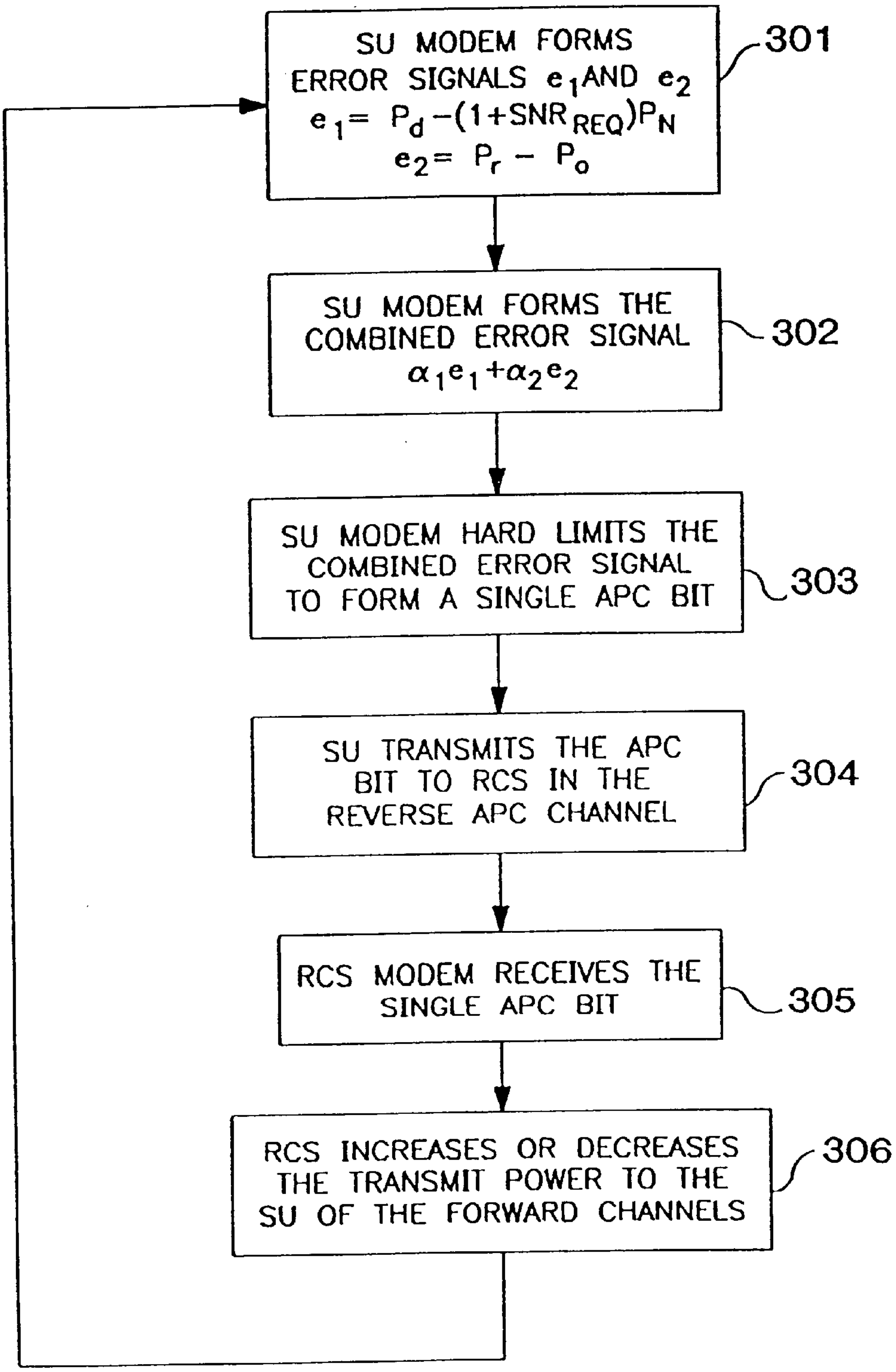

SU MODEM FORMS ERROR SIGNALS e_1 AND e_2
$e_1 = P_d - (1+SNR_{REQ})P_N$
$e_2 = P_r - P_o$
301
SU MODEM FORMS THE COMBINED ERROR SIGNAL $\alpha_1 e_1 + \alpha_2 e_2$
302
SU MODEM HARD LIMITS THE COMBINED ERROR SIGNAL TO FORM A SINGLE APC BIT
303
SU TRANSMITS THE APC BIT TO RCS IN THE REVERSE APC CHANNEL
304
RCS MODEM RECEIVES THE SINGLE APC BIT
305
RCS INCREASES OR DECREASES THE TRANSMIT POWER TO THE SU OF THE FORWARD CHANNELS
306

FIG. 3

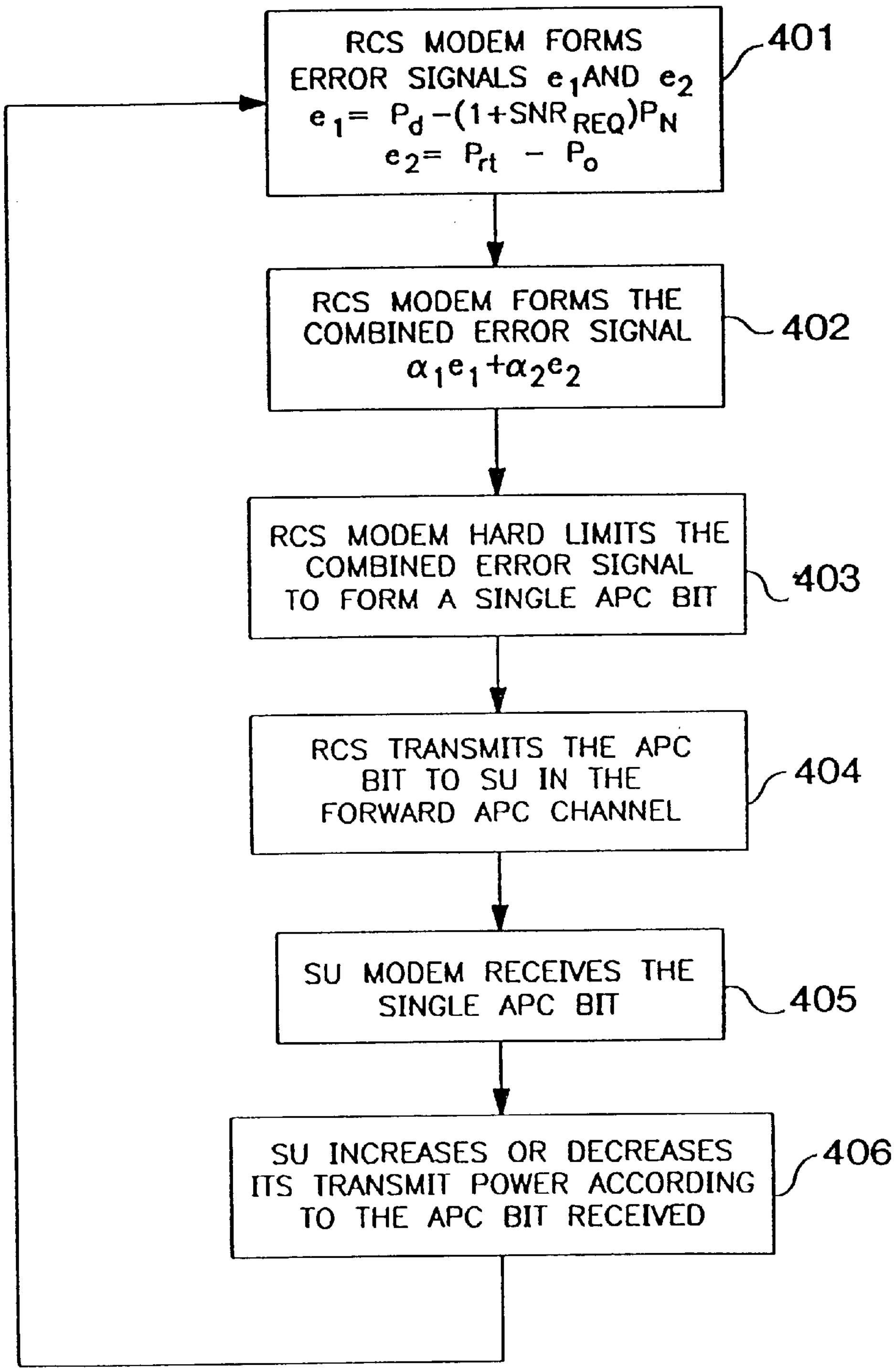

RCS MODEM FORMS ERROR SIGNALS e_1 AND e_2
$e_1 = P_d - (1+SNR_{REQ})P_N$
$e_2 = P_{rt} - P_o$
401
RCS MODEM FORMS THE COMBINED ERROR SIGNAL $\alpha_1 e_1 + \alpha_2 e_2$
402
RCS MODEM HARD LIMITS THE COMBINED ERROR SIGNAL TO FORM A SINGLE APC BIT
403
RCS TRANSMITS THE APC BIT TO SU IN THE FORWARD APC CHANNEL
404
SU MODEM RECEIVES THE SINGLE APC BIT
405
SU INCREASES OR DECREASES ITS TRANSMIT POWER ACCORDING TO THE APC BIT RECEIVED
406

FIG. 4

FIG. 5A

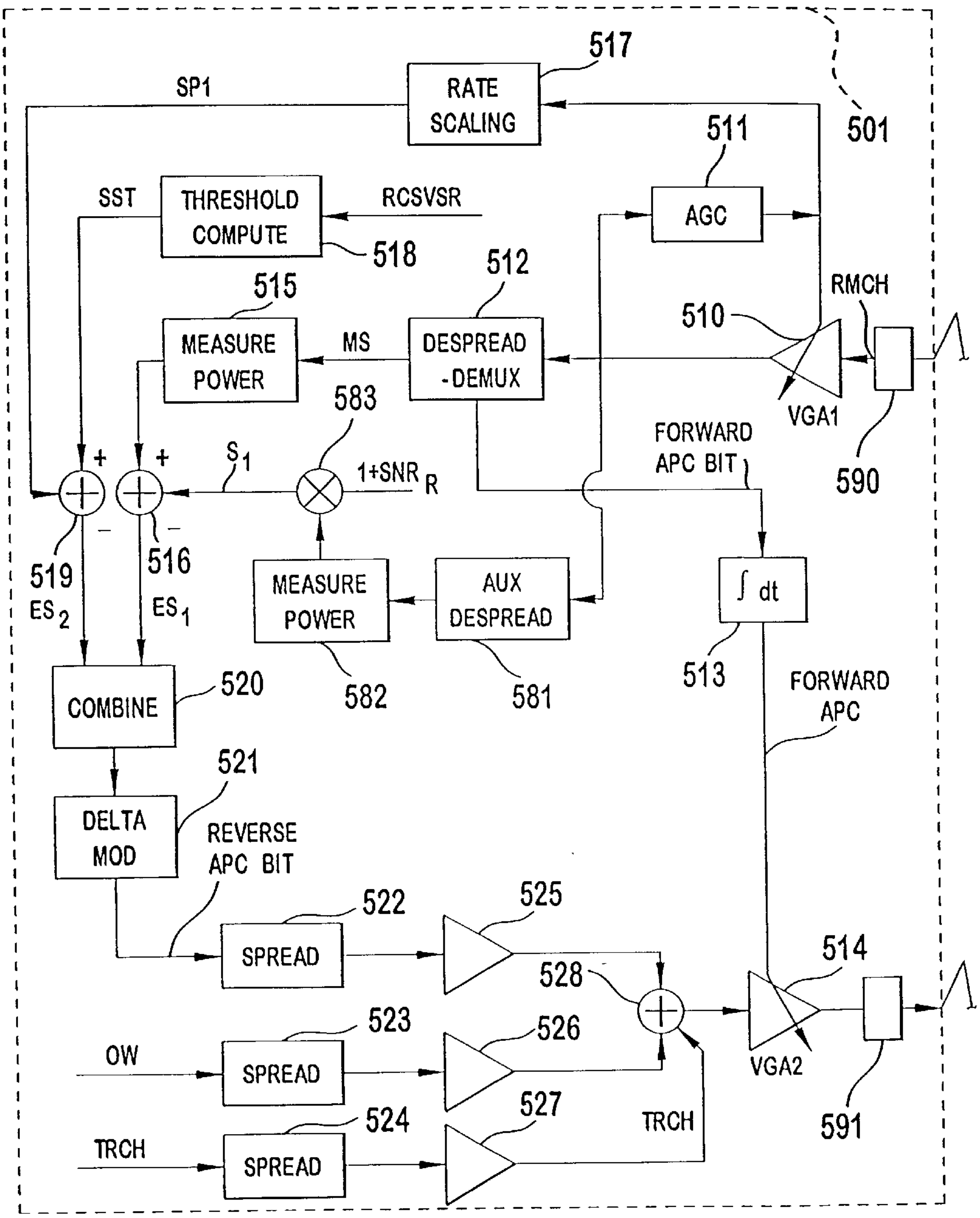
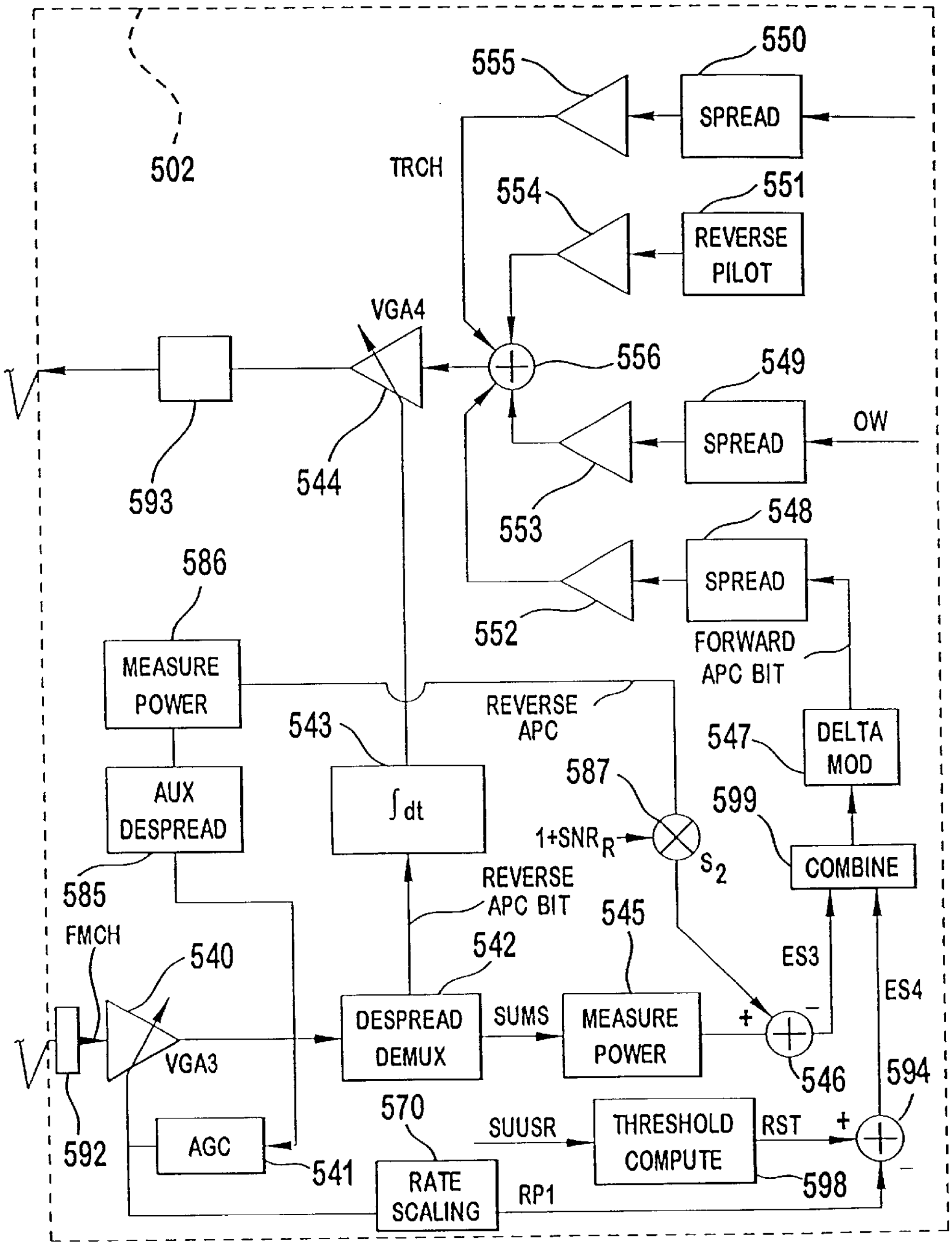
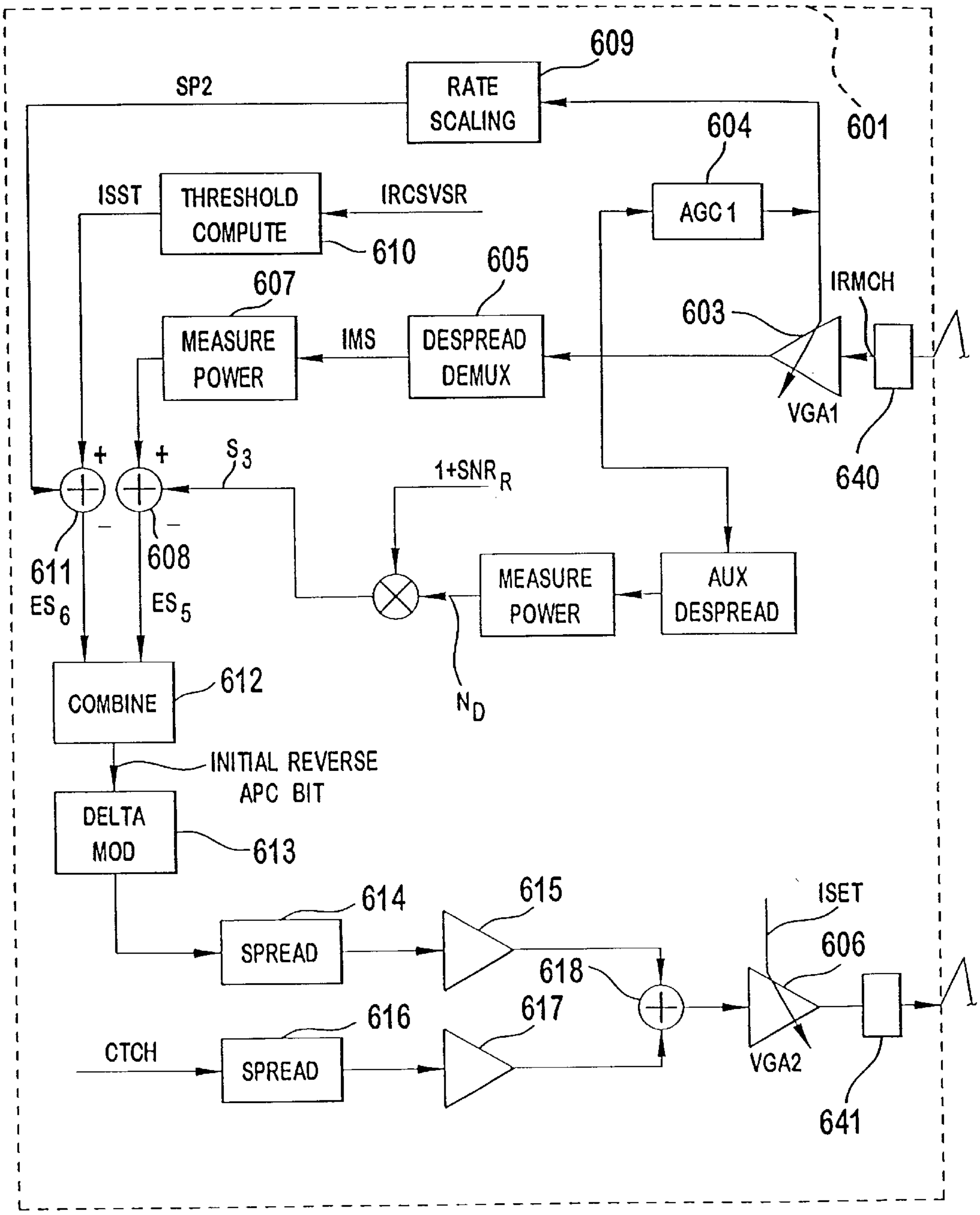

517
RATE SCALING
SP1
501
511
AGC
SST
THRESHOLD COMPUTE
RCSVSR
518
512
515
MEASURE POWER
MS
DESPREAD -DEMUX
RMCH
510
VGA1
583
FORWARD APC BIT
590
+
+
S1
1+SNR R
-
-
519
516
ES2
ES1
MEASURE POWER
AUX DESPREAD
∫ dt
COMBINE
520
582
581
513
FORWARD APC
521
DELTA MOD
REVERSE APC BIT
522
525
SPREAD
528
514
523
526
OW
SPREAD
VGA2
524
527
TRCH
TRCH
SPREAD
591

FIG. 5B



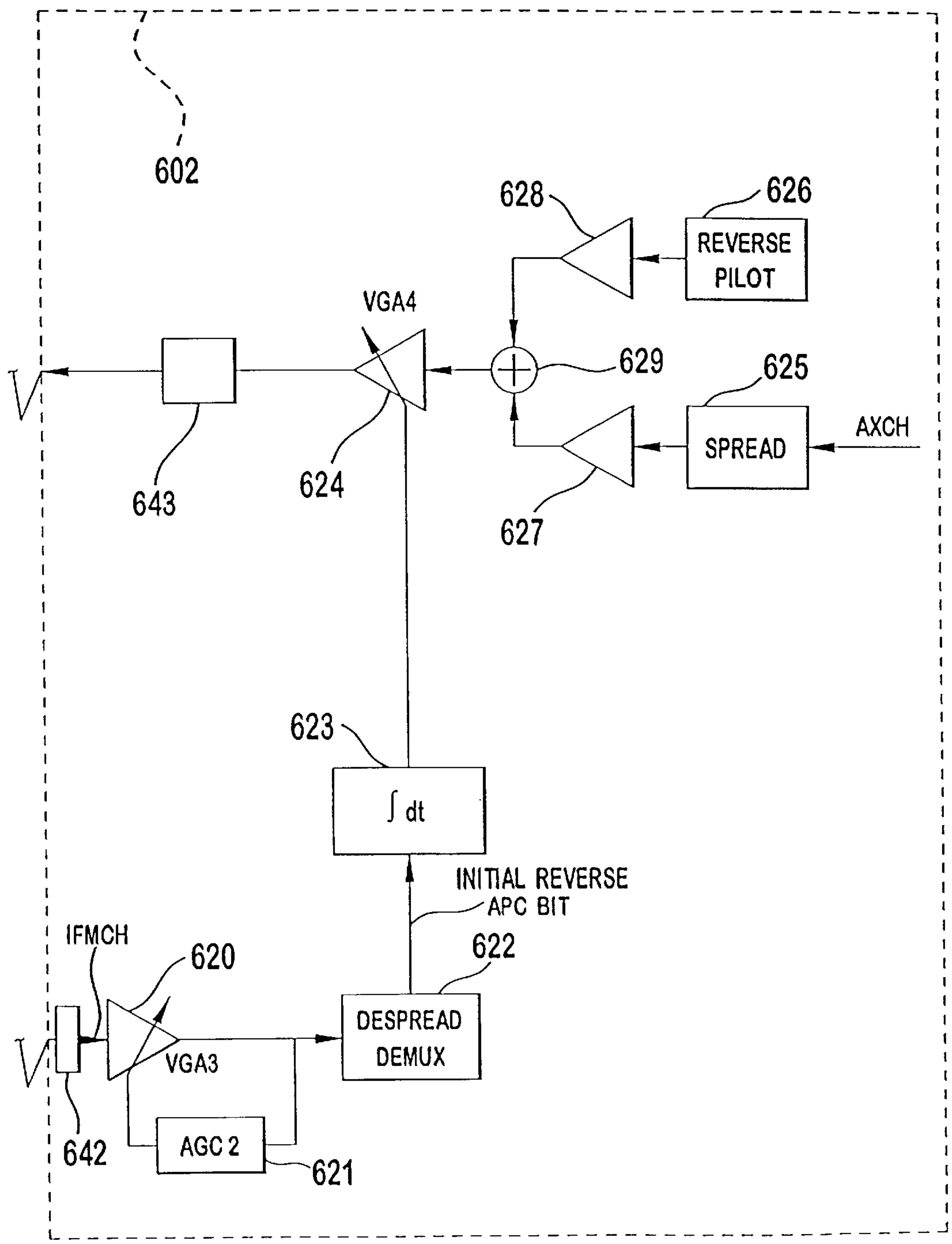
502
555
550
SPREAD
TRCH
554
551
REVERSE PILOT
VGA4
556
549
SPREAD
OW
593
544
553
548
SPREAD
586
552
FORWARD APC BIT
MEASURE POWER
REVERSE APC
543
547
DELTA MOD
AUX DESPREAD
∫dt
587
599
1+SNR_R
S_2
COMBINE
585
REVERSE APC BIT
545
FMCH
540
542
ES3
ES4
DESPREAD DEMUX
SUMS
MEASURE POWER
+
−
VGA3
546
594
570
SUUSR
THRESHOLD COMPUTE
RST
+
592
AGC
541
RATE SCALING
RP1
598
−

FIG. 6A



609
RATE SCALING
SP2
601
604
ISST
THRESHOLD COMPUTE
IRCSVSR
AGC 1
610
605
IRMCH
607
603
MEASURE POWER
IMS
DESPREAD DEMUX
VGA1
640
S3
1+SNRR
611
ES6
608
ES5
MEASURE POWER
AUX DESPREAD
COMBINE
612
ND
INITIAL REVERSE APC BIT
DELTA MOD
613
614
615
ISET
SPREAD
618
606
616
617
CTCH
SPREAD
VGA2
641

FIG. 6B


602
628
626
REVERSE PILOT
VGA4
629
625
AXCH
SPREAD
643
624
627
623
∫ dt
INITIAL REVERSE APC BIT
IFMCH
620
622
DESPREAD DEMUX
VGA3
642
AGC 2
621

AUTOMATIC POWER CONTROL SYSTEM FOR A CODE DIVISION MULTIPLE ACCESS (CDMA) COMMUNICATIONS SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 09/833,285, filed Apr. 12, 2001, which is a continuation of U.S. patent application Ser. No. 09/406,162, filed Sep. 27, 1999, now abandoned, which is a continuation of U.S. patent application Ser. No. 08/669,770, filed Jun. 27, 1996, now U.S. Pat. No. 5,991,329, which claims priority from Provisional patent application No. 60/000,775, filed Jun. 30, 1995, which applications are incorporated herein by reference.

BACKGROUND OF THE INVENTION

Providing quality telecommunication services to user groups which are classified as remote such as rural telephone systems and telephone systems in developing countries, has proved to be a challenge over recent years. These needs have been partially satisfied by wireless radio services, such as fixed or mobile frequency division multiplex (FDM), frequency division multiple access (FDMA), time division multiplex (TDM), time division multiple access (TDMA) systems, combination frequency and time division systems (FD/TDMA), and other land mobile radio systems. Usually, these remote services are faced with more potential users than can be supported simultaneously by their frequency or spectral bandwidth capacity.

Recognizing these limitations, recent advances in wireless communications have used spread spectrum modulation techniques to provide simultaneous communication by multiple users through a single communications channel. Spread spectrum modulation refers to modulating a information signal with a spreading code signal: the spreading code signal being generated by a code generator where the period Tc of the spreading code is substantially less than the period of the information data bit or symbol signal. The code may modulate the carrier frequency upon which the information has been sent, called frequency-hopped spreading, or may directly modulate the signal by multiplying the spreading code with the information data signal, called direct-sequence spreading (DS). Spread-spectrum modulation produces a signal having a bandwidth that is substantially greater than that required to transmit the information signal. Synchronous reception and despreading of the signal at the receiver demodulator recovers the original information. The synchronous demodulator uses a reference signal to synchronize the despreading circuits to the input spread-spectrum modulated signal to recover the carrier and information signals. The reference signal can be a spreading code which is not modulated by an information signal. Such use of a synchronous spread-spectrum modulation and demodulation for wireless communication is described in U.S. Pat. No. 5,228,056 entitled SYNCHRONOUS SPREAD-SPECTRUM COMMUNICATIONS SYSTEM AND METHOD by Donald L. Schilling, which is incorporated herein by reference.

Spread-spectrum modulation in wireless networks offers many advantages because multiple users may use the same frequency band with minimal interference to each user's receiver. In addition, spread spectrum modulation reduces effects from other sources of interference. Also, synchronous spread-spectrum modulation and demodulation techniques may be expanded by providing multiple message channels

for a user, each spread with a different spreading code, while still transmitting only a single reference signal to the user. Such use of multiple message In channels modulated by a family of spreading codes synchronized to a pilot spreading code for wireless communication is described in U.S. Pat. No. 5,166,951 entitled HIGH CAPACITY SPREAD-SPECTRUM CHANNEL by Donald L. Schilling, which is incorporated herein by reference.

Another problem associated with multiple access, spread-spectrum communication systems is the need to reduce the total transmitted power of users in the system, since users may have limited available power. An associated problem requiring power control in spread-spectrum systems is related to the inherent characteristic of spread-spectrum systems that one user's spread-spectrum signal is received by another user as noise with a certain power level. Consequently, users transmitting with high levels of signal power may interfere with other users' reception. Also, if a user moves relative to another user's geographic location, signal fading and distortion require that the users adjust their transmit power level to maintain a particular signal quality, and to maintain the power that the base station receives from all users. Finally, because it is possible for the spread-spectrum system to have more remote users than can be supported simultaneously, the power control system should also employ a capacity management method which rejects additional users when the maximum system power level is reached.

Prior spread-spectrum systems have employed a base station that measures a received signal and sends an adaptive power control (APC) signal to the remote users. Remote users include a transmitter with an automatic gain control (AGC) circuit which responds to the APC signal. In such systems the base station monitors to the overall system power or the power received from each user, and sets the APC signal accordingly. Such a spread-spectrum power control system and method is described in U.S. Pat. No. 5,299,226 entitled ADAPTIVE POWER CONTROL FOR A SPREAD SPECTRUM COMMUNICATION SYSTEM AND METHOD, and U.S. Pat. No. 5,093,840 entitled ADAPTIVE POWER CONTROL FOR A SPREAD SPECTRUM TRANSMITTER, both by Donald L. Schilling and incorporated herein by reference. This open loop system performance may be improved by including a measurement of the signal power received by the remote user from the base station, and transmitting an APC signal back to the base station to effectuate a closed loop power control method. Such closed loop power control is described, for 2) example, in U.S. Pat. No. 5,107,225 entitled HIGH DYNAMIC RANGE CLOSED LOOP AUTOMATIC GAIN CONTROL CIRCUIT to Charles E. Wheatley, III et al. and incorporated herein by reference.

These power control systems, however, exhibit several disadvantages. First, the base station must perform complex power control algorithms, increasing the amount of processing in the base station. Second, the system actually experiences several types of power variation: variation in the noise power caused by changing numbers of users and variations in the received signal power of a particular bearer channel. These variations occur with different frequency, so simple power control algorithms can be optimized only to one of the two types of variation. Finally, these power algorithms tend to drive the overall system power to a relatively high level. Consequently, there is a need for a spread-spectrum power control method that rapidly responds to changes in bearer channel power levels, while simultaneously making adjustments to all users' transmit power in response to changes in

the number of users. Also, there is a need for an improved spread-spectrum communication system employing a closed loop power control system which minimizes the system's overall power requirements while maintaining a sufficient BER at the individual remote receivers. In addition, such a system should control the initial transmit power level of a remote user and manage total system capacity.

SUMMARY OF THE INVENTION

A subscriber unit (SU) transmitter transmits signals over global and assigned channels to a base station which are initialized at an initial power level and adjusted to a controlled power level in advance of transmitting a communication data signal on an assigned channel to the base station. The power level of the SU transmitter is controlled to adjust the SU transmitter power level in response to power control signals received from the base station. The SU transmitter power level is monitored in advance of transmitting a communication data signal on an assigned channel to the base station. The transmitter is controlled such that transmission of a communication data signal on an assigned channel is blocked if a predetermined power limit is reached before commencing transmission of the communication data signal on the assigned channel.

BRIEF DESCRIPTION OF THE DRAWING(S)

FIG. **1** is a block diagram of a code division multiple access communication system according to the present invention.

FIG. **2** is a flow-chart diagram of an exemplary maintenance power control algorithm of the present invention.

FIG. **3** is a flow-chart diagram of an exemplary automatic forward power control algorithm of the present invention.

FIG. **4** is a flow-chart diagram of an exemplary automatic reverse power control algorithm of the present invention.

FIG. **5**A and FIG. **5**B is a block diagram of an exemplary closed loop power control system of the present invention when the bearer channel is established.

FIG. **6**A and FIG. **6**B is a block diagram of an exemplary closed loop power control system of the present invention during the process of establishing the bearer channel.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

The system of the present invention provides local-loop telephone service using radio link between one or more base stations and multiple remote subscriber units. In the exemplary embodiment, one radio link is described for a base station communicating with a fixed subscriber unit (FSU), but the system is equally applicable to systems including multiple base stations with radio links to both FSUs and Mobile Subscriber Units (MSUs). Consequently, the remote subscriber units are referred to herein as Subscriber Units (SUs).

Referring to FIG. **1**, Base Station (BS) **101** provides call connection to a local exchange (LE) **103** or any other telephone network switching interface, and includes a Radio Carrier Station (RCS) **104**. One or more RCSs **104**, **105**, **110** connect to a Radio Distribution Unit (RDU) **102** through links **131**, **132**, **137**, **138**, **139**, and RDU **102** interfaces with LE **103** by transmitting and receiving call set-up, control, and information signals through telco links **141**, **142**, **150**. SUs **116**, **119** communicate with the RCS **104** through RF links **161**, **162**, **163**, **164**, **165**. Alternatively, another embodiment of the invention includes several SUs and a "master" SU with functionality similar to the RCS. Such an embodiment may or may not have connection to a local telephone network.

Although the described embodiment uses different spread-spectrum bandwidths centered around a carrier for the transmit and receive spread-spectrum channels, the present method is readily extended to systems using multiple spread-spectrum bandwidths for the transmit channels and multiple spread-spectrum bandwidths for the receive channels. Alternatively, because spread-spectrum communication systems have the inherent feature that one user's transmission appears as noise to another user's despreading receiver, an embodiment can employ the same spread-spectrum channel for both the transmit and receive path channels. In other words, Uplink and Downlink transmissions can occupy the same frequency band. An embodiment of the invention may also employ multiple spread spectrum channels which need not be adjacent in frequency. In this embodiment, any channel may be used for Uplink, Downlink or Uplink and Downlink transmission.

In the exemplary embodiment, the spread binary symbol information is transmitted over the radio links **161** to **165** using Quadrature Phase Shift Keying (QPSK) modulation with Nyquist Pulse Shaping, although other modulation techniques may be used, including, but not limited to, Offset QPSK (OQPSK). Minimum Shift Keying (MSK), M-ary Phase Shift Keying (MPSK) and Gaussian Phase Shift Keying (GPSK).

The CDMA demodulator in either the RCS or the SU despreads the received signal with appropriate processing to combat or exploit multipath propagation effects. Parameters (concerning the received power level are used to generate the Automatic Power Control (APC) information which, in turn, is transmitted to the other end. The APC information is used to control transmit power of the automatic forward power control (AFPC) and automatic reverse power control (ARPC) links. In addition, each RCS **104**, **105** and **110** can perform Maintenance Power Control (MPC), in a manner similar to APC, to adjust the initial transmit power of each SU **111**, **112**, **115**, **117** and **118**. Demodulation is coherent where the pilot signal provides the phase reference.

The transmit power levels of the radio interface between RCS **104** and SUs **111**, **12**, **115**, **117** and **118** are controlled using two different closed loop power control algorithms. The Automatic Forward Power Control (AFPC) determines the Downlink transmit power level, and the Automatic Reverse Power Control (ARPC) determines the Uplink transmit power level. The logical control channel by which SU **111** and RCS **104**, for example, transfer power control information operates at least a 16 kHz update rate. Other embodiments may use a faster 32 kHz update rate. These algorithms ensure that the transmit power of a user maintains an acceptable Bit-Error Rate (BER), maintains the system power at a minimum to conserve power, and maintains the power level of all SUs **111**, **112**, **115**, **117** and **118**, as received by RCS **104**, at a nearly equal level.

In addition, the system includes an optional maintenance power algorithm that is used during the inactive mode of a SU. When SU **111** is inactive or powered-down to conserve power, the unit may occasionally activate itself and adjust its initial transmit power level setting in response to a maintenance power control signal from RCS **104**. The maintenance power signal is determined by the RCS **104** by measuring the received power level of SU **111** and present system power level and calculating the necessary initial transmit power. The method shortens the channel acquisition time of

SU **111** when it is turned on to begin a communication. The method also prevents the transmit power level of SU **111** from becoming too high and interfering with other channels during the initial transmission before the closed loop power control adjusts the transmit power to a level appropriate for the other message traffic in the channel.

The RCS **104** obtains synchronization of its clock from an interface line such as, but not limited to, E1, T1, or HDSL interfaces. Each RCS can also generate its own internal clock signal from an oscillator which may be regulated by a Global Positioning System (GPS) receiver. The RCS **104** generates a Global Pilot Code for a channel having a spreading code but no data modulation, which can be acquired by remote SUs **111** through **118**. All transmission channels of the RCS are synchronous with the Pilot channel, and spreading code phases of code generators (not shown) used for Logical communication channels within RCS **104** are also synchronous with the Pilot channel's spreading code phase. Similarly, SUs **111** through **118** which receive the Global Pilot Code of RCS **104** synchronize the spreading and de-spreading code phases of the code generators (not shown) of the SUs to the Global Pilot Code.

Logical Communication Channels

A 'channel' of the prior art is usually regarded as a communications path that is part of an interface and that can be distinguished from other paths of the interface without regard to its content. In the case of CDMA, however, separate communications paths are distinguished only by their content. The term 'logical channel' is used to distinguish the separate data streams, which are logically equivalent to channels in the conventional sense. All logical channels and sub-channels of the present invention are mapped to a common 64 kilo-symbols per second (ksym/s) QPSK stream. Some channels are synchronized to associated pilot codes which are generated and perform a similar function to the system Global Pilot Code. The system pilot signals are not, however, considered logical channels.

Several logical communication channels are used over the RF communication link between the RCS and SU. Each logical communication channel either has a fixed, predetermined spreading code or a dynamically assigned spreading code. For both predetermined and assigned codes, the code phase is synchronous with the Pilot Code. Logical communication channels are divided into two groups: the Global Channel (GC) group and the Assigned Channel (AC) group. The GC group includes channels which are either transmitted from the base station RCS to all the remote SUs or from any SU to the RCS of the base station regardless of the SU's identity. These channels typically contain information of a given type for all users. These channels include the channels used by the SUs to gain system access. Channels in the Assigned Channels (AC) group are those channels dedicated to communication between the RCS and a particular SU.

Power Control

General

The power control feature of the present invention is used to minimize the transmit power used between an RCS and any SUs with which it is in communication. The power control subfeature that updates transmit power during bearer channel connection is defined as automatic power control (APC). APC data is transferred from the RCS to an SU on the forward APC channel and from an SU to the RCS on the reverse APC channel. When there is no active data link between the two, the maintenance power control subfeature (MPC) controls the transmit to power of the SU.

Transmit power levels of forward and reverse assigned channels and reverse global channels are controlled by the APC algorithm to maintain sufficient signal power to interference noise power ratio (SIR) on those channels, and to stabilize and minimize system output power. The present invention uses a closed loop power control system in which a receiver controls its associated transmitter to incrementally raise or lower its transmit power. This control is conveyed to the associated transmitter via the power control signal on the APC channel. The receiver makes the decision to increase or decrease the transmitter's power based on two error signals. One error signal is an indication of the difference between the measured and required despread signal powers, and the other error signal is an indication of the average received total power.

As used in the described embodiment of the invention, the term near-end power control is used to refer to adjusting the transmitter's output power in accordance with the APC signal received on the APC channel from the other end. This means the reverse power control for the SU and forward power control for the RCS; and the term far-end APC is used to refer to forward power control for the SU and reverse power control for the RCS (adjusting the transmit power of the unit at the opposite end of the channel).

In order to conserve power, the SU modem terminates transmission and powers-down while waiting for a call, defined as the sleep phase. Sleep phase is terminated by an awaken signal from the SU controller. Responsive to this signal, the SU modem acquisition circuit automatically enters the reacquisition phase, and begins the process of acquiring the downlink pilot, as described below.

Closed Loop Power Control Algorithms

The near-end power control includes two steps: first, set the initial transmit power, second, continually adjust transmit power according to information received from the far-end using APC.

For the SU, initial transmit power is set to a minimum value and then ramped up, for example, at a rate of 1 dB/ms until either a ramp-up timer expires (not shown) or the RCS changes the corresponding traffic light value on the FBCH to "red" indicating the RCS has locked to the SU's short pilot signal (SAXPT). Expiration of the timer causes the SAXPT transmission to be shut down, unless the traffic light value is set to red first, in which case the SU continues to ramp-up transmit power but at a much lower rate than before the "red" signal was detected.

The initial power ramp-up method is described in U.S. Pat. No. 5,841,768 entitled A METHOD OF CONTROLLING INITIAL POWER RAMP-UP IN CDMA SYSTEMS BY USING SHORT CODES, is hereby incorporated by reference.

For the RCS, initial transmit power is set at a fixed value, corresponding to the minimum value necessary for reliable operation as determined experimentally for the service type and the current number of system users. Global channels, such as the Global Pilot or, the fast broadcast channel (FBCH), are always transmitted at the fixed initial power, whereas traffic channels are switched to APC.

The APC signal is transmitted as one bit signals on the APC channel. The one-bit signal represents a command to increase (signal is logic-high) or decrease (signal is logic-low) the associated transmit power. In the described embodiment, the 64 kbps APC data stream is not encoded or interleaved.

Far-end power control consists of the near-end transmitting power control information for the far-end to use in adjusting its transmit power.

The APC algorithm causes the RCS or the SU to transmit +1 if the following inequality holds, otherwise −1 (logic-low).

$$a_1e_1-a_2e_2>0 \tag{1}$$

Here the error signal e_1 is calculated as

$$e_1=P_d-(1+SNR_{REF})P_N \tag{2}$$

where P_d is the despread signal plus noise power, P_N is the despread noise power, and SNR_{REF} is the desired despread signal to noise ratio for the particular service type; and

$$e_2=P_r-P_0 \tag{3}$$

where Pr is a measure of the received power and Po is the automatic gain control (AGC) circuit set point. The weights α_1 and α_2 in equation (30) are chosen for each service type and for the APC update rate.

Maintenance Power Control

During the sleep phase of the SU, the interference noise power of the CDMA RF channel changes. As an alternative to the initial power ramp-up method described above, the present invention may include a maintenance power control feature (MPC) which periodically adjusts the SU's initial transmit power with respect to the interference noise power of the CDMA channel. The MPC is the process whereby the transmit power level of an SU is maintained within close proximity of the minimum level required for the RCS to detect the SU's signal. The MPC process compensates for low frequency changes in the required SU transmit power.

The maintenance control feature uses two global channels: one is called the status channel (STCH) on reverse link, and the other is called the check-up channel (CUCH) on forward link. The signals transmitted on these channels carry no data and they are generated the same way the short codes used in initial power ramp-up are generated. The STCH and CUCH codes are generated from a "reserved" branch of the global code generator.

The MPC process is as follows. At random intervals, the SU sends a symbol length spreading code periodically for 3 ms on the status channel (STCH). If the RCS detects the sequence, it replies by sending a symbol length code sequence within the next 3 ms on the check-up channel (CUCH). When the SU detects the response from the RCS, it reduces its transmit power by a particular step size. If the SU does not detect any response from the RCS within the 3 ms period, it increases its transmit power by the step size. Using this method, the RCS response is transmitted at a power level that is enough to maintain a 0.99 detection probability at all SU's.

The rate of change of traffic load and the number of active users is related to the total interference noise power of the CDMA channel. The update rate and step size of the maintenance power update signal for the present invention is determined by using queuing theory methods well known in the art of communication theory, such as outlined in "Fundamentals of Digital Switching" (Plenum-New York) edited by McDonald and incorporated herein by reference. By modeling the call origination process as an exponential random variable with mean 6.0 mins, numerical computation shows the maintenance power level of a SU should be updated once every 10 seconds or less to be able to follow the changes in interference level using 0.5 dB step size. Modeling the call origination process as a Poisson random variable with exponential interarrival times, arrival rate of 2×10^{-4} per second per user, service rate of 1/360 per second, and the total subscriber population is 600 in the RCS service area also yields by numerical computation that an update rate of once every 10 seconds is sufficient when 0.5 dB step size is used.

Maintenance power adjustment is performed periodically by the SU which changes from sleep phase to awake phase and performs the MPC process. Consequently, the process for the MPC feature is shown in FIG. **2** and is as follows: First, at step **201**, signals are exchanged between the SU and the RCS maintaining a transmit power level that is close to the required level for detection: the SU periodically sends a symbol length spreading code in the STCH, and the RCS sends periodically a symbol length spreading code in the CUCH as response.

Next, at step **202**, if the SU receives a response within 3 ms after the STCH message it sent, it decreases its transmit power by a particular step size at step **203**; but if the SU does not receive a response within 3 ms after the STCH message, it increases its transmit power by the same step size at step **204**.

The SU waits, at step **205**, for a period of time before sending another STCH message, this time period is determined by a random process which averages 10 seconds.

Thus, the transmit power of the STCH messages from the SU is adjusted based on the RCS response periodically, and the transmit power of the CUCH messages from the RCS is fixed.

Mapping of Power Control Signal to Logical Channels For APC

Power control signals are mapped to specified Logical Channels for controlling transmit power levels of forward and reverse assigned channels. Reverse global channels are also controlled by the APC algorithm to maintain sufficient signal power to interference noise power ratio (SIR) on those reverse channels, and to stabilize and minimize system output power. The present invention uses a closed loop power control method in which a receiver periodically decides to incrementally raise or lower the output power of the transmitter at the other end. The method also conveys that decision back to the respective transmitter.

TABLE 1

APC Signal Channel Assignments

Link Channels and Signals	Call/Connection Status	Power Control Method: Initial Value	Power Control Method: Continuous
Reverse link AXCH AXPT	Being Established	as determined by power ramping	APC bits in forward APC channel
Reverse link APC, OW, TRCH, pilot signal	In-Progress	level established during call set-up	APC bits in forward APC channel
Forward link APC, OW, TRCH	In-Progress	fixed value	APC bits in reverse APC channel

Forward and reverse links are independently controlled. For a call/connection in process, forward link traffic channel (TRCH) APC, and Order Wire (OW) power is controlled by the APC bits transmitted on the reverse APC channel.

During the call/connection establishment process, reverse link access channel (AXCH) power is also controlled by the APC bits transmitted on the forward APC channel. Table 1 summarizes the specific power control methods for the controlled channels.

The required SIRs of the assigned channels TRCH, APC and OW and reverse assigned pilot signal for any particular SU are fixed in proportion to each other and these channels are subject to nearly identical fading, therefore, they are power controlled together.

Automatic Forward Power Control

The AFPC system attempts to maintain the minimum required SIR on the forward channels during a call/connection. The AFPC recursive process shown in FIG. **3** consists of the steps of having an SU form the two error signals e_1 and e_2 in step **301** where

$$e_1=P_d-(1+SNR_{REQ})P_N \tag{4}$$

$$e_2=P_r-P_0 \tag{5}$$

and P_d is the despread signal plus noise power, P_N is the despread noise power, SNR_{REF} is the required signal to noise ratio for the service type, P_r is a measure of the total received power, and P_o is the AGC set point. Next, the SU modem forms the combined error signal $\alpha_1e_1+\alpha_2e_2$ in step **302**. Here, the weights α_1 and α_2 are chosen for each service type and APC update rate. In step **303**, the SU hard limits the combined error signal and forms a single APC bit. The SU transmits the APC bit to the RCS in step **304** and RCS modem receives the bit in step **305**. The RCS increases or decreases its transmit power to the SU in step **306** and the algorithm repeats starting from step **301**.

Automatic Reverse Power Control

The ARPC system maintains the minimum required SIR on the reverse channels to minimize the total system reverse output power, during both call/connection establishment and while the call/connection is in progress. The ARPC recursive process shown in FIG. **4** begins at step **401** where the RCS modem forms the two error signals e_1 and e_2 in step **401** where

$$e_1=P_d-(1+SNR_{REQ})P_N \tag{6}$$

$$e_2=P_{rt}-P_o \tag{7}$$

SIR and Multiple Channel Types

The required SIR for channels on a link is a function of channel format (e.g. TRCH, OW). service type (e.g. ISDN B, 32 kb/s ADPCM POTS) and the number of symbols over which data bits are distributed (e.g. two 64 kb/s symbols are integrated to form a single 32 kb/s ADPCM POTS symbol). Despreader output power corresponding to the required SIR for each channel and service type is predetermined. While a call/connection is in progress, several user CDMA logical channels are concurrently active; each of these channels transfers a symbol every symbol period. The SIR of the symbol from the nominally highest SIR channel is measured, compared to a threshold and used to determine the APC step up/down decision each symbol period. Table 2 indicates the symbol (and threshold) used for the APC computation by service and call type.

APC Parameters

APC information is always conveyed as a single bit of information, and the APC Data Rate is equivalent to the APC

Update Rate. The APC update rate is 64 kb/s. This rate is high enough to accommodate expected Rayleigh and Doppler fades, and allow for a relatively high (~0.2) Bit Error Rate (BER) in the Uplink and Downlink APC channels, which minimizes capacity devoted to the APC.

The power step up/down indicated by an APC bit is nominally between 0.1 and 0.01 dB. The dynamic range for power control is 70 dB on the reverse link and 12 dB on the forward link for the exemplary embodiment of the present system. and P_d is the despread signal plus noise power, P_N is the despread noise power. SNR_{REF} is the reference signal to noise ratio for the service type, P_{rt} is a measure of the average total power received by the RCS, and P_o is the AGC set point. The RCS modem forms the combined error signal $\alpha_1e_1+\alpha_2e_2$ in step **402** and hard limits this error signal to determine a single APC bit in step **403**. The RCS transmits the APC bit to the SU in step **404**, and the bit is received by the SU in step **405**. Finally, SU adjusts its transmit power according to the received APC bit in step **406**, and the process repeats starting from step **401**.

TABLE 2

Symbols/Thresholds Used for APC Computation

Service or Call Type	Call/Connection Status	Symbol (and Threshold) Used for APC Decision
Don't care	Being Established	AXCH
ISDN D SU	In-Progress	one 1/64-KBPS symbol from TRCH (ISDN-D)
ISDN 1B + D SU	In-Progress	TRCH (ISDN-B)
ISDN 2B + D SU	In-Progress	TRCH (one ISDN-B)
POTS SU (64 KBPS PCM)	In-Progress	one 1/64-KBPS symbol from TRCH, use 64 KBPS PCM threshold
POTS SU (32 KBPS ADPCM)	In-Progress	one 1/64-KBPS symbol from TRCH, use 32 KBPS ADPCM threshold
Silent Maintenance Call (any SU)	In-Progress	OW (continuous during a maintenance call)

An Alternative Embodiment for Multiplexing APC Information

The dedicated APC and OW logical channels described previously can also be multiplexed together in one logical channel. The APC information is transmitted at 64 kb/s. continuously whereas the OW information occurs in data bursts. The alternative multiplexed logical channel includes the unencoded, non-interleaved 64 kb/s. APC information on, for example, the In-phase channel and the OW information on the quadrature channel of the QPSK signal.

Closed Loop Power Control Implementation

The closed loop power control during a call connection responds to two different variations in overall system power. First, the system responds to local behavior such as changes in power level of an SU, and second, the system responds to changes in the power level of the entire group of active users in the system.

The Power Control system of the exemplary embodiment of the present invention is shown in FIG. **5**A and FIG. **5**B. As shown, the circuitry used to adjust the transmitted power is similar for the RCS (shown as the RCS power control module **501**) and SU (shown as the SU power control module **502**). Beginning with the RCS power control module **501**, the reverse link RF channel signal is received at the RF antenna **590** and demodulated to produce the reverse

CDMA signal RMCH which is applied to the variable gain amplifier (VGA1) **510**. The output signal of VGA1 **510** is provided to the Automatic Gain Control (AGC) Circuit **511** which produces a variable gain amplifier control signal into the VGA1 **510**. This signal maintains the level or the output signal of VGA1 **510** at a near constant value. The output signal of VGA1 is despread by the despread-demultiplexer (demux) **512** which produces a despread user message signal MS and a forward APC bit. The forward APC bit is applied to the integrator **513** to produce the Forward APC control signal. The Forward APC control signal controls the Forward Link VGA2 **514** and maintains the Forward Link RF channel signal at a minimum level necessary for communication.

The signal power of the despread user message signal MS of the RCS power module **501** is measured by the power measurement circuit **515** to produce a signal power indication. The output of the VGA1 is also despread by the AUX despreader **581** which despreads the signal by using an uncorrelated spreading code, and hence obtains a despread noise signal. The power measurement taken at power measurement device **582** of this signal is multiplied at multiplier **583** by 1 plus the required signal to noise ratio (SNR_R) to form the threshold signal S1. The difference between the despread signal power and the threshold value S1 is produced by the subtracter **516**. This difference is the error signal ES1 which is an error signal relating to the particular SU transmit power level. Similarly the control signal for the VGA1 **510** is applied to the rate scaling circuit **517** to reduce the rate of the control signal for VGA1 **510**. The output signal of scaling circuit **517** is a scaled system power level signal SP1. The Threshold Compute logic **518** computes the System Signal Threshold SST value from the RCS user channel power data signal (RCSUSR). The complement of the Scaled system power level signal, SP1, and the System Signal Power Threshold value SST are applied to the adder **519** which produces second error signal ES2. This error signal is related to the system transmit power level of all active SUs. The input Error signals ES1 and ES2 are combined in the combiner **520** produce a combined error signal input to the delta modulator (DM1) **521**, and the output signal of the DM1 is the reverse APC bit stream signal, having bits of value +1 or −1, which for the present invention is transmitted as a 64 kb/sec signal.

The Reverse APC bit is applied to the spreading circuit **522** and the output signal of the spreading circuit **522** is the spread-spectrum forward APC message signal. Forward OW and Traffic signals are also provided to spreading circuits **523**, **524**, producing forward traffic message signals 1, 2, . . . N. The power level of the forward APC signal, the forward OW, and traffic message signals are adjusted by the respective amplifiers **525**, **526** and **527** to produce the power level adjusted forward APC, OW, and TRCH channels signals. These signals are combined by the adder **528** and applied to the VAG2 **514**, which produces forward link RF channel signal. The forward link RF channel signal is transmitted by transmitter **591**.

The forward link RF channel signal including the spread forward APC signal is received by the RF antenna **592** of the SU, and demodulated to produce the forward CDMA signal FMCH. This signal is provided to the variable gain amplifier (VGA3) **540**. The output signal of VGA3 is applied to the Automatic Gain Control Circuit (AGC) **541** which produces a variable gain amplifier control signal to VGA3 **540**. This signal maintains the level of the output signal of VGA3 at a near constant level. The output signal of VAG3 **540** is despread by the despread demux **542**, which produces a despread user message signal SUMS and a reverse APC bit. The reverse APC bit is applied to the integrator **543** which produces the Reverse APC control signal. This reverse APC control signal is provided to the Reverse APC VGA4 **544** to maintain the Reverse link RF channel signal at a minimum power level.

The despread user message signal SUMS is also applied to the power measurement circuit **545** producing a power measurement signal which is added to the complement of threshold value S2 in the adder **546** to produce error signal ES3. The signal ES3 is an error signal relating to the RCS transmit power level for the particular SU. To obtain threshold S2, the despread noise power indication at measure power device **586** from the AUX despreader **585** is multiplied at multiplier **587** by 1 plus the desired signal lo noise ratio SNR_R. The AUX despreader **585** despreads the input data using an uncorrelated spreading code, hence its output is an indication of the despread noise power.

Similarly, the control signal for the VGA3 is applied to the rate scaling circuit **570** to reduce the rate of the control signal for VGA3 in order to produce a scaled received power level RP1 (see FIG. **5**A and FIG. **5**B). The threshold compute **598** circuit computes the received signal threshold RST from SU measured power signal SUUSR. The complement of the scaled received power level RP1 and the received signal threshold RST are applied to the adder **594** which produces error signal ES4. This error is related to the RCS transmit power to all other SUs. The input error signals ES3 and ES4 are combined in the combiner **599** and input to the delta modulator DM2 **547**, and the output signal of DM2 **547** is the forward APC bit stream signal, with bits having value of value +1 or −1. In the exemplary embodiment of the present invention this signal is transmitted as a 64 kb/sec signal.

The Forward APC bit stream signal is applied to the spreading circuit **2948** to produce the output reverse spread-spectrum APC signal. Reverse OW and Traffic signals are also input to spreading circuits **549**, **550**, producing reverse OW and traffic message signals 1, 2 . . . N and the reverse pilot is generated by the reverse pilot generator **551**. The power level of the reverse APC message signal reverse OW message signal, reverse pilot, and the reverse traffic message signals are adjusted by amplifiers **552**, **553**, **554**, **555** to produce the signals which are combined by the adder **556** and input to the reverse APC VGA4 **544**. It is this VGA4 **544** which produces the reverse link RF channel signal. The reverse link RF channel signal is transmitted by transmitter **593**.

During the call connection and bearer channel establishment process, the closed loop power control of the present invention is modified, and is shown in FIG. **6**A and FIG. **6**B. As shown, the circuits used to adjust the transmitted power are different for the RCS, shown as the Initial RCS power control module **601**; and for the SU, shown as the Initial SU power control module **602**. Beginning with the Initial RCS power control module **601**, the reverse link RF channel signal is received at the RF antenna **640** and demodulated producing the reverse CDMA signal IRMCH which is received by the first variable gain amplifier (VGA **1**) **603**. The output signal of VGA1 is detected by the Automatic Gain Control Circuit (AGC1) **604** which provides a variable gain amplifier control signal to VGA1 **603** to maintain the level of the output signal of VAG1 at a near constant value. The output signal of VGA1 is despread by the despread demultiplexer **605** which produces a despread user message signal IMS. The Forward APC control signal, ISET, is set to a fixed value, and is applied to the Forward Link Variable

Gain Amplifier (VGA**2**) **606** to set the Forward Link RF channel signal at a predetermined level.

The signal power of the despread user message signal IMS of the Initial RCS power module **601** is measured by the power measure circuit **607**, and the output power measurement is subtracted from a threshold value S**3** in the subtracter **608** to produce error signal ES**5** which is an error signal relating to the transmit power level of a particular SU. The threshold S**3** is calculated by multiplying at multiplier **652** the despread power measurement at measure power device **651** obtained from the AUX despreader **650** by 1 plus the desired signal to noise ratio SNR. The AUX despreader **650** despreads the signal using an uncorrelated spreading code, hence its output signal is an indication of despread noise power. Similarly, the VGA**1** control signal is applied to the rate scaling circuit **609** to reduce the rate of the VGA**1** control signal in order to produce a scaled system power level signal SP**2**. The threshold computation logic **610** determines an Initial System Signal Threshold value (ISST) computed from the user channel power data signal (IRCSUSR). The complement of the scaled system power level signal SP**2** and the (ISST) are provided to the adder **611** which produces a second error signal ES**6**, which is an error signal relating to the system transmit power level of all active SUs. The value of ISST is the desired transmit power for a system having the particular configuration. The input Error signals ES**5** and ES**6** are combined in the combiner **612** produce a combined error signal input to the delta modulator (DM**3**) **613**. DM**3** produces the initial reverse APC bit stream signal, having bits of value +1 or −1, which for the present invention is transmitted as a 64 kb/sec signal.

The Reverse APC bit stream signal is applied to the spreading circuit **614**. to produce the initial spread-spectrum forward APC signal. The control channel (CTCH) information is spread by the spreader **616** to form the spread CTCH message signal. The spread APC and CTCH signals are scaled by the amplifiers **615** and **617** and combined by the combiner **618**. The combined signal is applied to VAG**2** **606** which produces the forward link RF channel signal. The forward link RF channel signal is transmitted by transmitter **641**.

The forward link RF channel signal including the spread forward APC signal is received by the RF antenna **642** of the SU and demodulated to produce the initial forward CDMA signal (IFMCH) which is applied to the variable gain amplifier (VGA**3**) **620**. The output signal of VGA**3** is detected by the Automatic Gain Control Circuit (AGC**2**) **621** which produces a variable gain amplifier control signal for the VGA**3** **620**. This signal maintains the output power level of the VGA**3** **620** at a near constant value. The output signal of VAG**3** is despread by the despread demultiplexer **622** which produces an initial reverse APC bit that is dependent on the output level of VGA**3**. The reverse APC bit is processed by the integrator **623** to produce the Reverse APC control signal. The Reverse APC control signal is provided to the Reverse APC VGA**4** **624** to maintain Reverse link RF channel signal at a defined power level the reverse link RF channel signal is transmitted by transmitter **643**.

The global channel AXCH signal is spread by the spreading circuits **625** to provide the spread AXCH channel signal. The reverse pilot generator **626** provides a reverse pilot signal, and the signal power of AXCH and the reverse pilot signal are adjusted by the respective amplifiers **627** and **628**. The spread AXCH channel signal and the reverse pilot signal are added by the adder **629** to produce reverse link CDMA signal. The reverse link CDMA signal is received by the reverse APC VGA**4** **624**, which produces the reverse link RF channel signal output to the RF transmitter.

System Capacity Management

The system capacity management algorithm of the present invention optimizes the maximum user capacity for an RCS area, called a cell. When the SU comes within a certain value of maximum transmit power, the SU sends an alarm message to the RCS. The RCS sets the traffic lights which control access to the system, to "red" which, as previously described, is a flag that inhibits access by the SU's. This condition remains in effect until the alarming SU terminates its call, or until the transmit power of the alarming SU, measured at the SU, is a value less than the maximum transmit power. When multiple SUs send alarm messages, the condition remains in effect until either all calls from alarming SUs terminate, or until the transmit power of the alarming SU, measured at the SU, is a value less than the maximum transmit power. An alternative embodiment measures the bit error rate measurements from the Forward Error Correction (FEC) decoder, and holds the RCS traffic lights at "red" until the bit error rate is less than a predetermined value.

The blocking strategy of the present invention includes a method which uses the power control information transmitted from the RCS to an SU, and the received power measurements at the RCS. The RCS measures its transmit power level, detects that a maximum value is reached, and determines when to block new users. An SU preparing to enter the system blocks itself if the SU reaches the maximum transmit power before successful completion of a bearer channel assignment.

Each additional user in the system has the effect of increasing the noise level for all other users, which decreases the signal to noise ratio (SNR) that each user experiences. The power control algorithm maintains a desired SNR for each user. Therefore, in the absence of any other limitations, addition of a new user into the system has only a transient effect and the desired SNR is regained.

The transmit power measurement at the RCS is done by measuring either the root mean square (rms) value of the baseband combined signal or by measuring the transmit power of the RF signal and feeding it back to digital control circuits. The transmit power measurement may also be made by the SUs to determine if the unit has reached its maximum transmit power. The SU transmit power level is determined by measuring the control signal of the RF amplifier, and scaling the value based on the service type, such as plain old telephone service (POTS), FAX, or integrated services digital network (ISDN).

The information that an SU has reached the maximum power is transmitted to the RCS by the SU in a message on the Assigned Channels. The RCS also determines the condition by measuring reverse APC changes because, if the RCS sends APC messages to the SU to increase SU transmit power, and the SU transmit power measured at the RCS is not increased, the SU has reached the maximum transmit power.

The RCS does not use traffic lights to block new users who have finished ramping-up using the short codes. These users are blocked by denying them the dial tone and letting them time out. The RCS sends all 1's (go down commands) on the APC Channel to make the SU lower its transmit power. The RCS also sends either no CTCH message or a message with an invalid address which would force the FSU to abandon the access procedure and start over. The SU does not start the acquisition process immediately because the traffic lights are red.

When the RCS reaches its transmit power limit, it enforces blocking in the same manner as when an SU

reaches its transmit power limit. The RCS turns off all the traffic lights on the FBCH, starts sending all I APC bits (go down commands) to those users who have completed their short code ramp-up but have not yet been given dial tone, and either sends no CTCH message to these users or sends messages with invalid addresses to force them to abandon the access process.

The self blocking algorithm of the SU is as follows. When the SU starts transmitting the AXCH, the APC starts its power control operation using the AXCH and the SU transmit power increases. While the transmit power is increasing under the control of the APC, it is monitored by the SU controller. If the transmit power limit is reached, the SU abandons the access procedure and starts over.

Although the invention has been described in terms of an exemplary embodiment, it is understood by those skilled in the art that the invention may be practiced with modifications to the embodiment that are within the scope of the invention as defined by the following claims:

What is claimed is:

1. A method of self blocking for a subscriber unit (SU) which conducts wireless communication with a base station in a spread spectrum communication system using code division multiple access, the method comprising:

providing a SU transmitter for transmitting signals over global and assigned channels to a base station which are initialized at a initial power level and adjusted to a controlled power level in advance of transmitting a communication data signal on an assigned channel to the base station;

controlling the power level of said SU transmitter to adjust the SU transmitter power level in response to power control signals received from the base station; and

monitoring the SU transmitter power level in advance of transmitting a communication data signal on an assigned channel to the base station and controlling the transmitter such that transmission of a communication data signal on an assigned channel is blocked if a predetermined power limit is reached before commencing transmission of the communication data signal on the assigned channel.

2. The method of claim **1** wherein said transmitter is configured to transmit a plurality of types of communication data signals and SU transmitter power level is determined based in part on the type of communication data signal to be transmitted.

3. The method of claim **1** wherein said transmitter is configured to transmit a plurality of types of communication data signals including plain old telephone service (POTS), FAX and integrated services digital network (ISDN) and includes an RF amplifier controlled by a control signal to transmit the SU's signals as RF signals and SU transmitter power level is determined based on the type of communication data signal to be transmitted and the RF amplifier control signal.

4. The method of claim **1** wherein said controlling the power level of said transmitter to adjust the SU transmitter power level is in response to power control signals received from the base station on a global channel.

5. The method of claim **2** wherein said controlling the power level of said transmitter to adjust the SU transmitter power level is in response to power control signals received from the base station on a global channel.

6. The method of claim **3** wherein said controlling the power level of said transmitter to adjust the SU transmitter power level is in response to power control signals received from the base station on a global channel.

7. A subscriber unit (SU) having self blocking control for wireless communication with a base station in a spread spectrum communication system using code division multiple access, the SU comprising:

a transmitter for transmitting signals over global and assigned channels to a base station which are initialized at a initial power level and adjusted to a controlled power level in advance of transmitting a communication data signal on an assigned channel to the base station;

a receiver and associated circuitry for controlling the power level of said transmitter;

said receiver and associated circuitry configured to adjust the SU transmitter power level in response to power control signals received from the base station; and

control circuitry for monitoring the SU transmitter power level in advance of transmitting a communication data signal on an assigned channel to the base station and controlling the transmitter such that transmission of a communication data signal on an assigned channel is blocked if a predetermined power limit is reached before commencing transmission of the communication data signal on the assigned channel.

8. The SU of claim **7** wherein said transmitter is configured to transmit a plurality of types of communication data signals and said control circuitry is configured to determine transmitter power level based in part on the type of communication data signal to be transmitted.

9. The SU of claim **7** wherein:

said transmitter is configured to transmit a plurality of types of communication data signals including plain old telephone service (POTS), FAX and integrated services digital network (ISDN) and includes an RF amplifier controlled by a control signal to transmit the SU's signals as RF signals; and

said control circuitry is configured to determine transmitter power level based on the type of communication data signal to be transmitted and the RF amplifier control signal.

10. The SU of claim **7** wherein said receiver and associated circuitry is configured to adjust the SU transmitter power level is in response to power control signals received from the base station on a global channel.

11. The SU of claim **8** wherein said receiver and associated circuitry is configured to adjust the SU transmitter power level is in response to power control signals received from the base station on a global channel.

12. The SU of claim **9** wherein said receiver and associated circuitry is configured to adjust the SU transmitter power level is in response to power control signals received from the base station on a global channel.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,674,791 B2
DATED : January 6, 2004
INVENTOR(S) : Lomp et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

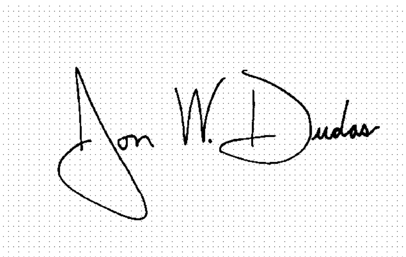
Column 4,
Line 44, after the word "111," delete "12" and insert therefore -- 112 --.

Column 7,
Line 7, delete "a_1e_1-a_2e_2>0" and insert -- $\alpha_1 e_1$-$\alpha_2 e_2$>0 --.

Column 12,
Line 15, after the word "signal", delete "lo" and insert therefore -- to --.

Signed and Sealed this

Twenty-fifth Day of May, 2004



JON W. DUDAS
Acting Director of the United States Patent and Trademark Office

EXHIBIT C

US006973579B2

(12) **United States Patent**
Dick et al.

(10) **Patent No.: US 6,973,579 B2**
(45) **Date of Patent: Dec. 6, 2005**

(54) **GENERATION OF USER EQUIPMENT IDENTIFICATION SPECIFIC SCRAMBLING CODE FOR THE HIGH SPEED SHARED CONTROL CHANNEL**

(75) Inventors: **Stephen G. Dick**, Nesconset, NY (US); **Nader Bolourchi**, Larchmont, NY (US); **Sung-Hyuk Shin**, Fort Lee, NJ (US)

(73) Assignee: **InterDigital Technology Corporation**, Wilmington, DE (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 260 days.

(21) Appl. No.: **10/187,640**

(22) Filed: **Jul. 1, 2002**

(65) **Prior Publication Data**

US 2003/0210782 A1 Nov. 13, 2003

Related U.S. Application Data

(60) Provisional application No. 60/378,170, filed on May 13, 2002, and provisional application No. 60/378,509, filed on May 7, 2002.

(51) **Int. Cl.**[7] **G06F 11/30**; H04K 1/00; H04B 1/69

(52) **U.S. Cl.** **713/200**; 380/2; 380/210; 375/135; 375/146

(58) **Field of Search** 713/200; 380/210, 380/217, 218, 221, 2; 375/135, 136, 141, 145, 146, 147; 370/320, 335, 342, 441, 510

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Siemens, "Simplified UE–ID Masking of HS–SCCH, Part 1," Discussion and Decision, TSG–RAN Working Group 1 #27, Oulu, Finland, Jul. 2–5, 2002.

InterDigital Comm. Corp., "16 bit UE ID based UE Specific Masking for HS–SCCH: Updated for consistency with new Rate matching for HS–SCCH," Discussion and Decision, 3GPP TSG RAN WG1#27, Olou, FInland, Jul. 2–5, 2002.

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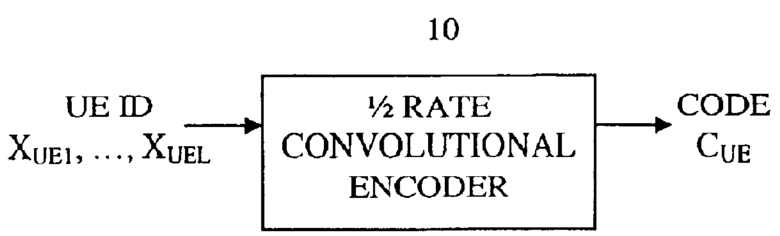
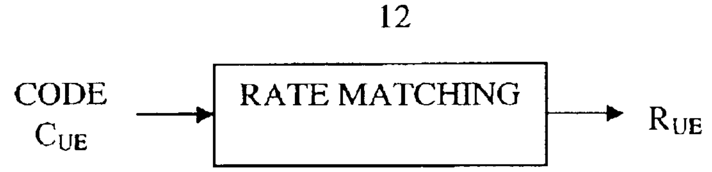
Primary Examiner—Emmanuel L. Moise
(74) *Attorney, Agent, or Firm*—Volpe and Koenig, P.C.

(57) **ABSTRACT**

A code is produce for use in scrambling or descrambling data associated with a high speed shared control channel (HS-SSCH) for a particular user equipment. A user identification of the particular user equipment comprises L bits. A ½ rate convolutional encoder processes at least the bits of the user identification by a ½ rate convolutional code to produce the code.

10 Claims, 2 Drawing Sheets





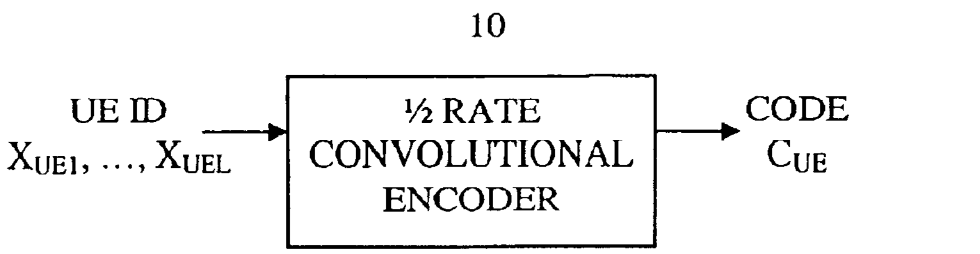


FIG. 1A

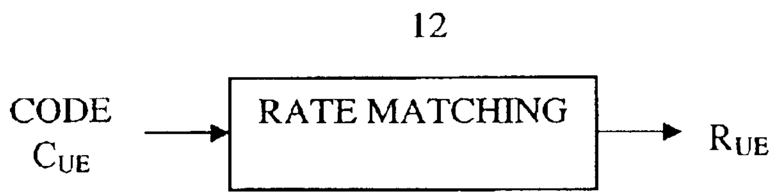


FIG. 1B

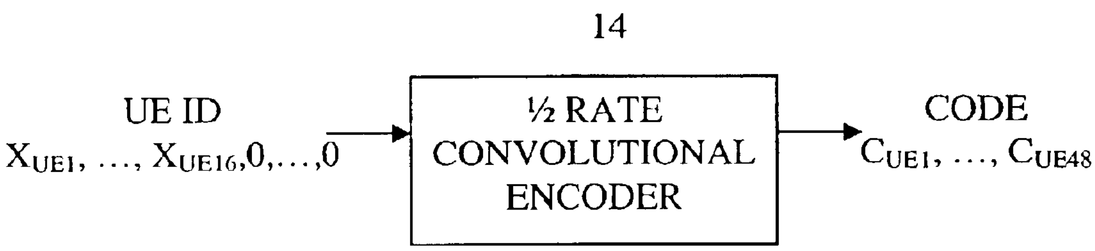


FIG. 2A

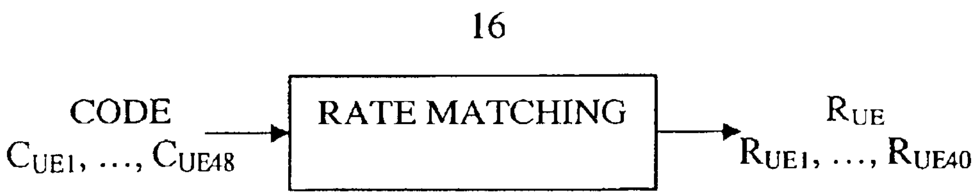


FIG. 2B

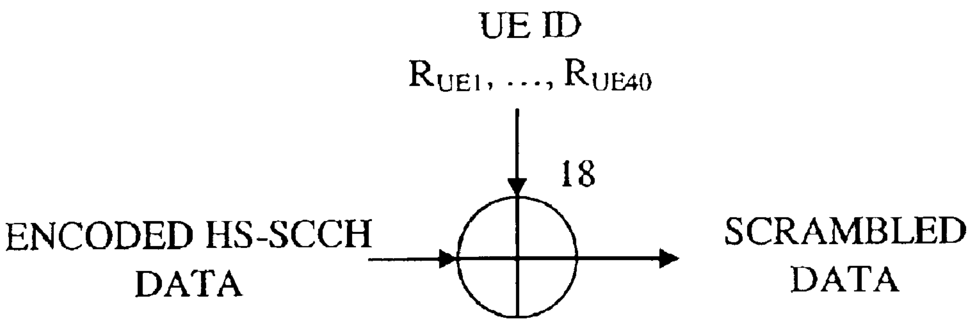

UE ID
$R_{UE1}, \ldots, R_{UE40}$
18
ENCODED HS-SCCH DATA
SCRAMBLED DATA

FIG. 3

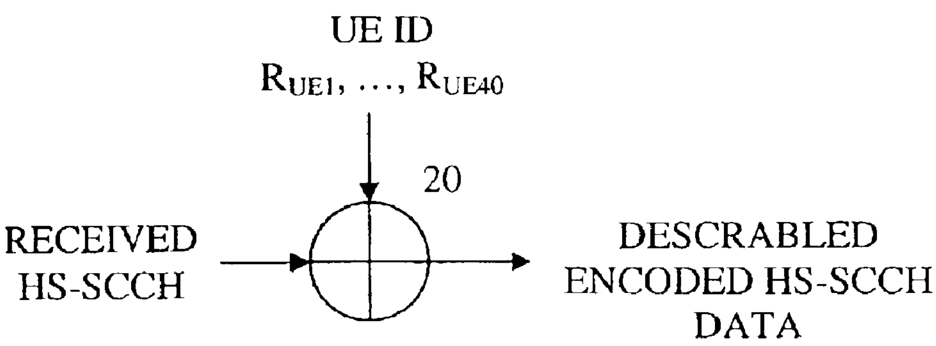

UE ID
$R_{UE1}, \ldots, R_{UE40}$
20
RECEIVED HS-SCCH
DESCRABLED ENCODED HS-SCCH DATA

FIG. 4

GENERATION OF USER EQUIPMENT IDENTIFICATION SPECIFIC SCRAMBLING CODE FOR THE HIGH SPEED SHARED CONTROL CHANNEL

This application claims priority to U.S. Provisional Application No. 60/378,170, filed May 13, 2002 and to U.S. Provisional Application No. 60/378,509, filed May 7, 2002.

BACKGROUND

The present invention relates to wireless communication systems. More particularly, the present invention relates to user equipment identification specific scrambling sequences for high speed shared control channels (HS-SCCH).

A high speed downlink packet access (HSDPA) is proposed for wideband code division multiple access communication systems. HSDPA allows for high downlink data rates to support multimedia services.

To support HSDPA, high speed shared control channels (HS-SCCHs) are used. The HS-SCCHs are used to signal vital control information to the user equipments (UEs). Each HS-SCCH has two parts, referred to as Part-1 and Part-2. Part-1 carries time critical information needed by the UE. This information includes the channelization code set and the modulation type used by the high speed physical downlink shared control channel (HS-PDSCH) which carries the HSDPA payload. This information is vital to support HSDPA, since HSDPA uses adaptive modulation and coding (AMC).

To obtain its Part-1 information, each HSDPA UE monitors up to four HS-SCCHs for its information. The information for a particular UE is distinguished from other UEs by its UE identification (UE ID) specific scrambling sequence. The UE processes each monitored HS-SCCH with its UE ID specific scrambling sequence to detect the HS-SCCH intended for the UE. After processing, the UE determines on which HS-SCCH, if any, information was carried using its scrambling sequence. The UE descrambles the data carried on Part-1 of its HS-SCCH using its scrambling sequence.

Until recently, a 10 bit UE ID was used as the basis for the UE ID specific scrambling sequence. In this case, this UE ID was converted into a 40 bit scrambling sequence. To turn the 10 bit UE ID into the 40 bit UE ID specific scrambling sequence, the 10 bit UE ID is processed by a Reed-Muller block to produce a 32 bit code. The first 8 bits of the produced code are repeated and appended onto the back of the 32 bit code to produce a 40 bit code.

Although it is proposed to extend the UE ID length to 16 chips, the current proposal for the HS-SCCHs uses a 10 bit UE ID. This UE ID is converted into a 40 bit scrambling sequence. To turn the 10 bit UE ID into the 40 bit scrambling sequence, the 10 bit UE ID is processed by a Reed-Muller block to produce a 32 bit code. The first 8 bits of the produced code are repeated and appended onto the back of the 32 bit code to produce a 40 bit code.

To reduce the occurrence of false detections, it is desirable to have good separation between the produced scrambling codes for each UE ID. Accordingly, it is desirable to have alternate approaches to producing scrambling codes.

SUMMARY

A code is produced for use in scrambling or descrambling data associated with a high speed shared control channel (HS-SSCH) for a particular user equipment. A user identification of the particular user equipment comprises L bits. A ½ rate convolutional encoder processes at least the bits of the user identification by a ½ rate convolutional code to produce the code.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a preferred diagram of a circuit for producing a code associated with a particular user for a HS-SCCH.

FIG. **1**B is a diagram of a rate matching block used in conjunction with FIG. **1**A.

FIG. **2**A is a preferred diagram of a circuit for producing a code associated with a user identification of 16 bits.

FIG. **2**B is a diagram of a rate matching block used in conjunction with FIG. **2**A.

FIG. **3** is a simplified user equipment using the UE ID specific scrambling code.

FIG. **4** is a simplified base station using the UE ID specific scrambling code.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Although the preferred embodiments are described in conjunction with the preferred application of the invention for use with the HSDPA of the third generation partnership project (3GPP) wideband code division multiple access (W-CDMA) communication system, the invention can be applied to other code division multiple access communication systems. FIGS. **1**A and **1**B are diagrams of a preferred UE ID specific scrambling sequence circuit. A UE ID, X_{UE}, of length L is input into the circuit. L can be any length, such as 8 bits, 10 bits, 16 bits, etc. The UE ID, $X_{UE}=\{X_{UE1}, \ldots, X_{UEL}\}$, is input into a ½ rate convolutional encoder **10** as shown in FIG. **1**A. Along with the UE ID, extra bits, such as zeros, may be added to the end of the input string to extend the length of the input string and, accordingly, the output string. The use of a ½ rate convolutional encoder **10** provides for a high level of code separation between the output strings produced by different UE IDs. Additionally, current proposed 3GPP W-CDMA communication systems utilize a ½ rate convolutional encoder **10** for a forward error correction (FEC) technique. Accordingly, no additional hardware is required to generate the convolutionally encoded UE ID specific scrambling sequence. After encoding, based on the length of the output string, a rate matching stage **12** may be added to puncture bits to obtain a desired string length.

FIGS. **2**A and **2**B are diagrams of preferred UE ID specific scrambling sequence circuit for a preferred UE ID codes of length 16, L=16. The 16 bit UE ID, $X_{UE}=\{X_{UE1}, \ldots, X_{UE16}\}$, is input into a ½ rate convolutional encoder **14** along with eight zero bits appended onto the end of the input string. As a result, the input string is $X_{UE1}, \ldots, X_{UE16}$, 0, 0, 0, 0, 0, 0, 0, 0. After being processed by the ½ rate convolutional encoder **14**, the output code is 48 bits in length, $C_{UE}=\{C_{UE1}, \ldots, C_{UE48}\}$.

To reduce the length of the code to a preferred length of 40 bits, eight bits are preferably punctured. FIG. **2**B illustrates the rate matching stage **16** to perform the puncturing. After the rate matching stage **16**, the effective length of the scrambling code is 40 bits.

FIG. **4** is a simplified diagram of a user equipment descrambling a HS-SCCH using the UE ID specific scrambling code. The UE ID scrambling code is mixed, such as by exclusive-or gate **18**, with the received HS-SCCH for use in recovering the encoded HS-SCCH data.

FIG. **3** is a simplified diagram of a base station scrambling encoded data with the UE ID specific scrambling code for

transfer over the HS-SCCH. The encoded data is mixed with the UE ID scrambling code, such as by an exclusive-or gate **20**, for a particular user. The scrambled data is used to produce the HS-SCCH for transfer to the particular user.

What is claimed is:

1. An apparatus comprising:

an input configured to accept a user identification comprising L bits; and

a ½ rate convolutional encoder for processing at least the bits of the user identification by a ½ rate convolutional code to produce a code used for scrambling a high speed shared control channel (HS-SCCH).

2. The apparatus of claim **1** further comprising a rate matching block for puncturing bits after the production of the ½ rate convolutional code.

3. A user equipment comprising:

an input configured to accept a 16 bit user identification; and

a ½ rate convolutional encoder for processing the 16 bit user identification code with eight appended zero bits to produce a 48 bit code for use in descrambling a high speed shared control channel (HS-SCCH).

4. The user equipment of claim **3** further comprising a rate matching block for puncturing eight bits after the production of the 48 bit code.

5. A user equipment comprising:

an input configured to accept a 16 bit user identification; and

means for ½ rate convolutional encoding the 16 bit user identification code with eight appended zero bits to produce a 48 bit code for use in descrambling a high speed shared control channel (HS-SCCH).

6. The user equipment of claim **5** further comprising means for puncturing eight bits after the production of the 48 bit code.

7. A base station comprising:

an input configured to accept a 16 bit user identification; and

a ½ rate convolutional encoder for processing the 16 bit user identification code with eight appended zero bits to produce a 48 bit code for use in scrambling a high speed shared control channel (HS-SCCH) for a user equipment associated with the 16 bit user identification.

8. The base station of claim **7** further comprising a rate matching block for puncturing eight bits after the production of the 48 bit code.

9. A base station comprising:

an input configured to accept a 16 bit user identification; and

means for ½ rate convolutional encoding the 16 bit user identification code with eight appended zero bits to produce a 48 bit code for use in scrambling a high speed shared control channel (HS-SCCH) for a user equipment associated with the 16 bit user identification.

10. The base station of claim **9** further comprising means for puncturing eight bits after the production of the 48 bit code.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,973,579 B2
APPLICATION NO. : 10/187640
DATED : December 6, 2005
INVENTOR(S) : Dick et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

TITLE PAGE, ITEM (56), OTHER PUBLICATIONS, page 1, right column, line 10, after "WG1#27," delete "Olou, FInland," and insert therefor --Oulu, Finland--.

IN THE ABSTRACT

TITLE PAGE, ITEM (57), line 1, after the word "is", delete "produce" and insert therefor --produced--.

IN THE DRAWINGS

FIG. 3, delete "DESCRABLED" and insert therefor --DESCRAMBLED--.

At column 1, line 67, before the words “for a”, delete “(HS-SSCH)” and insert therefor --(HS-SCCH)--.

Signed and Sealed this

Twenty-second Day of August, 2006

JON W. DUDAS
Director of the United States Patent and Trademark Office

EXHIBIT D

US007190966B2

(12) **United States Patent**
Ozluturk et al.

(10) **Patent No.: US 7,190,966 B2**
(45) **Date of Patent: *Mar. 13, 2007**

(54) **METHOD AND APPARATUS FOR PERFORMING AN ACCESS PROCEDURE**

(75) Inventors: **Fatih Ozluturk**, Port Washington, NY (US); **Gary R. Lomp**, Centerport, NY (US)

(73) Assignee: **InterDigital Technology Corporation**, Wilmington, DE (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 106 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **11/169,490**

(22) Filed: **Jun. 29, 2005**

(65) **Prior Publication Data**

US 2005/0249166 A1 Nov. 10, 2005

Related U.S. Application Data

(63) Continuation of application No. 10/866,851, filed on Jun. 14, 2004, now Pat. No. 7,117,004, which is a continuation of application No. 10/400,343, filed on Mar. 26, 2003, now Pat. No. 6,839,567, which is a continuation of application No. 10/086,320, filed on Mar. 1, 2002, now Pat. No. 6,571,105, which is a continuation of application No. 09/721,034, filed on Nov. 22, 2000, now Pat. No. 6,493,563, which is a continuation of application No. 09/003,104, filed on Jan. 6, 1998, now Pat. No. 6,181,949, which is a continuation of application No. 08/670,162, filed on Jun. 27, 1996, now Pat. No. 5,841,768.

(51) **Int. Cl.**
H04B 7/00 (2006.01)
H04B 7/216 (2006.01)
H04B 1/00 (2006.01)

(52) **U.S. Cl.** **455/522**; 455/69; 455/517; 370/335; 370/342; 375/145; 375/146

(58) **Field of Classification Search** 455/522, 455/69, 67.11, 226.1, 422.1, 517; 375/145, 375/146, 140, 147, 354, 356, 365, 362; 370/335, 370/342, 441, 310, 321, 329, 330, 336, 337, 370/345, 347, 350, 311, 474
See application file for complete search history.

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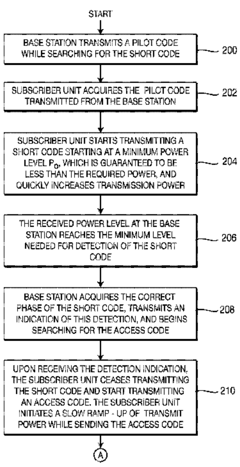
(Continued)

Primary Examiner—Lana Le
(74) *Attorney, Agent, or Firm*—Volpe and Koenig, P.C.

(57) **ABSTRACT**

A base station for controlling transmission power during the establishment of a communication channel utilizes the reception of a short code during initial power ramp-up. The short code is a sequence for detection by the base station which has a much shorter period than a conventional access code. The ramp-up starts from a power level that is lower than the required power level for detection by the base station. The power of the short code is quickly increased until the signal is detected by the base station. Once the base station detects the short code, it transmits an indication that the short code has been detected.

12 Claims, 11 Drawing Sheets



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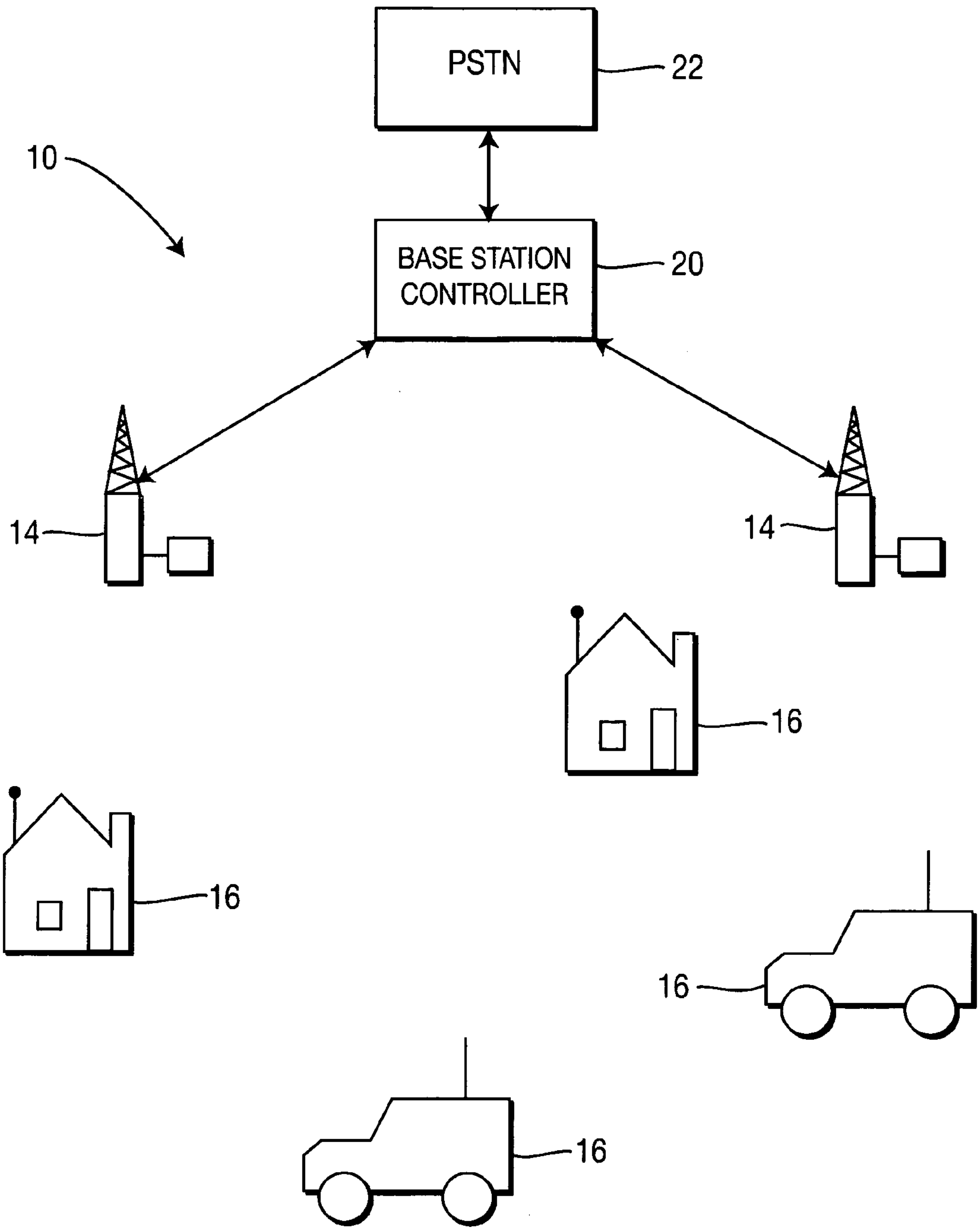


FIG. 1

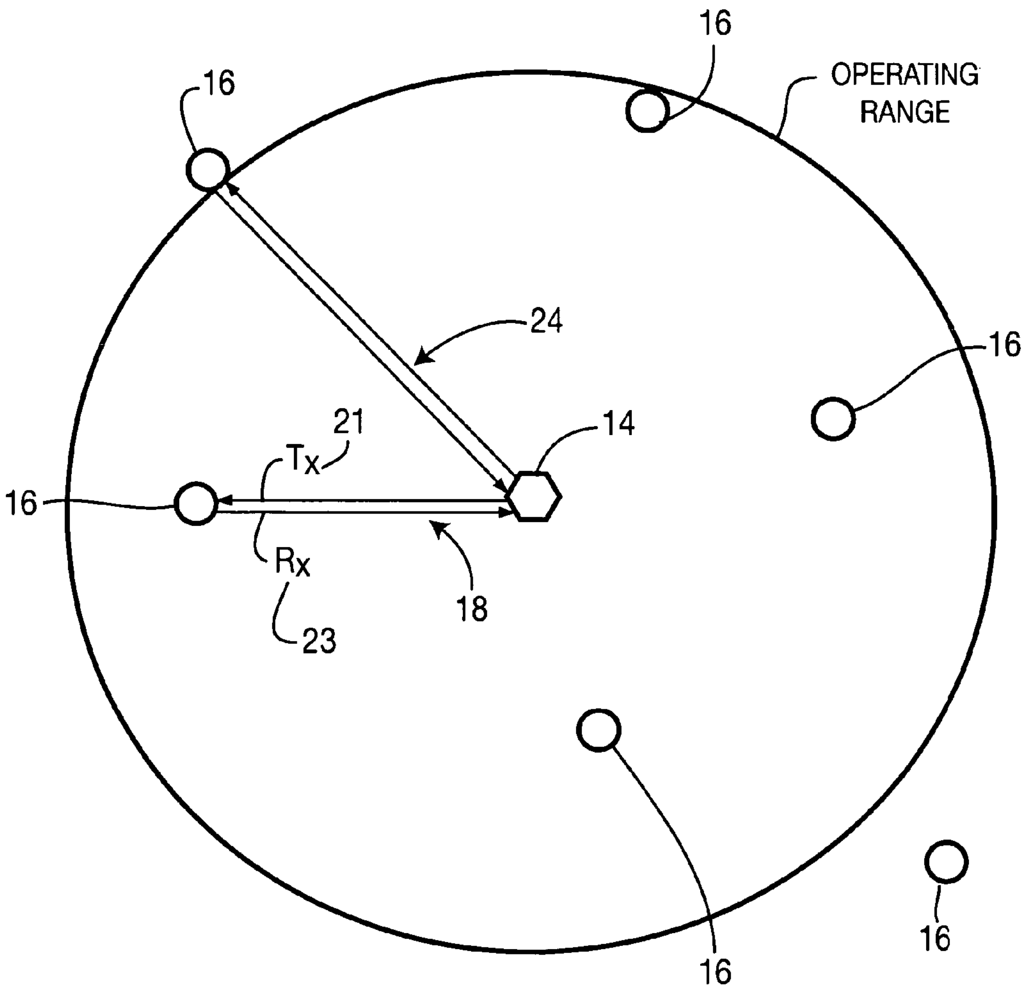
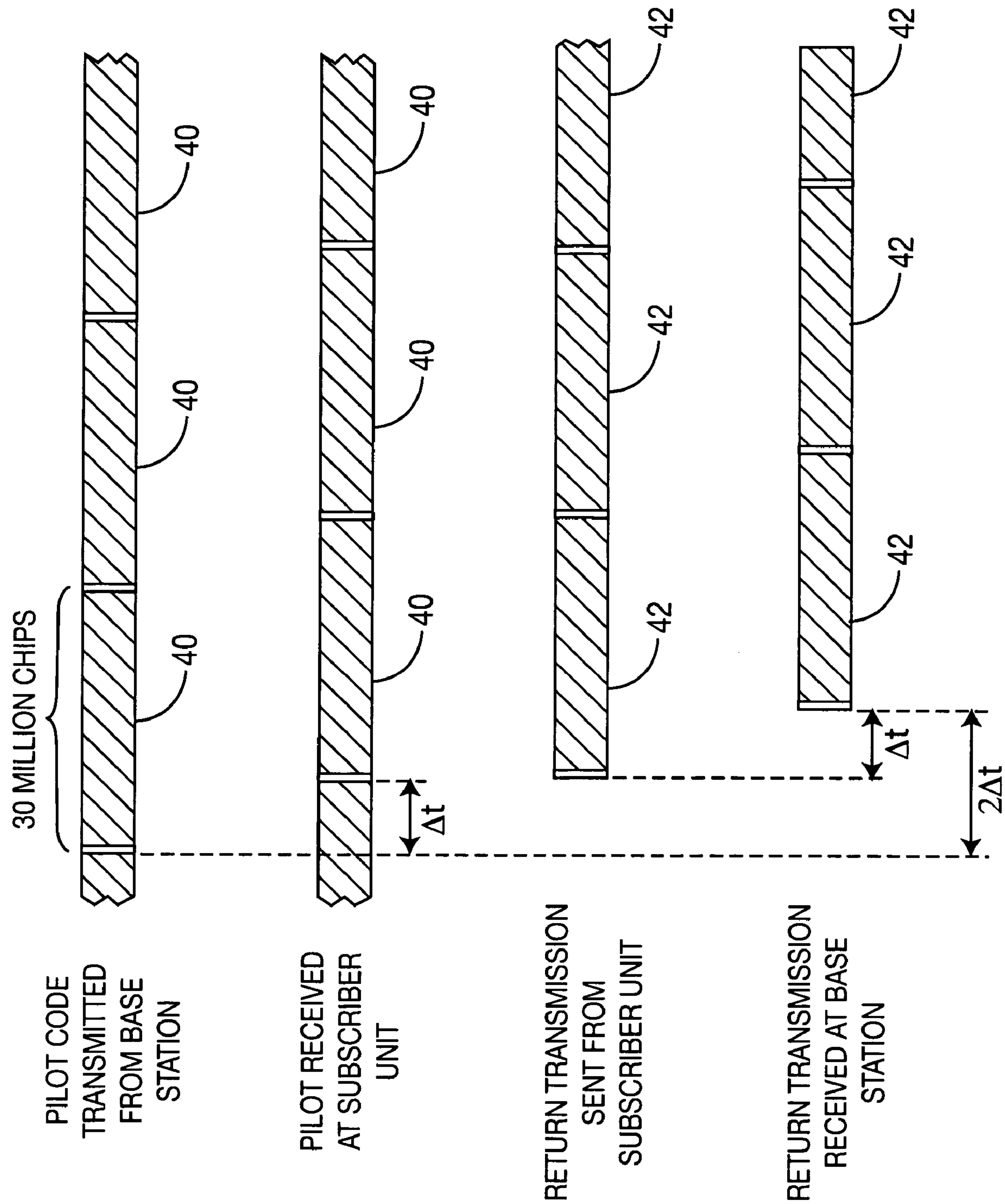


FIG. 2

FIG. 3


30 MILLION CHIPS
40
42
Δt
2Δt
PILOT CODE TRANSMITTED FROM BASE STATION
PILOT RECEIVED AT SUBSCRIBER UNIT
RETURN TRANSMISSION SENT FROM SUBSCRIBER UNIT
RETURN TRANSMISSION RECEIVED AT BASE STATION

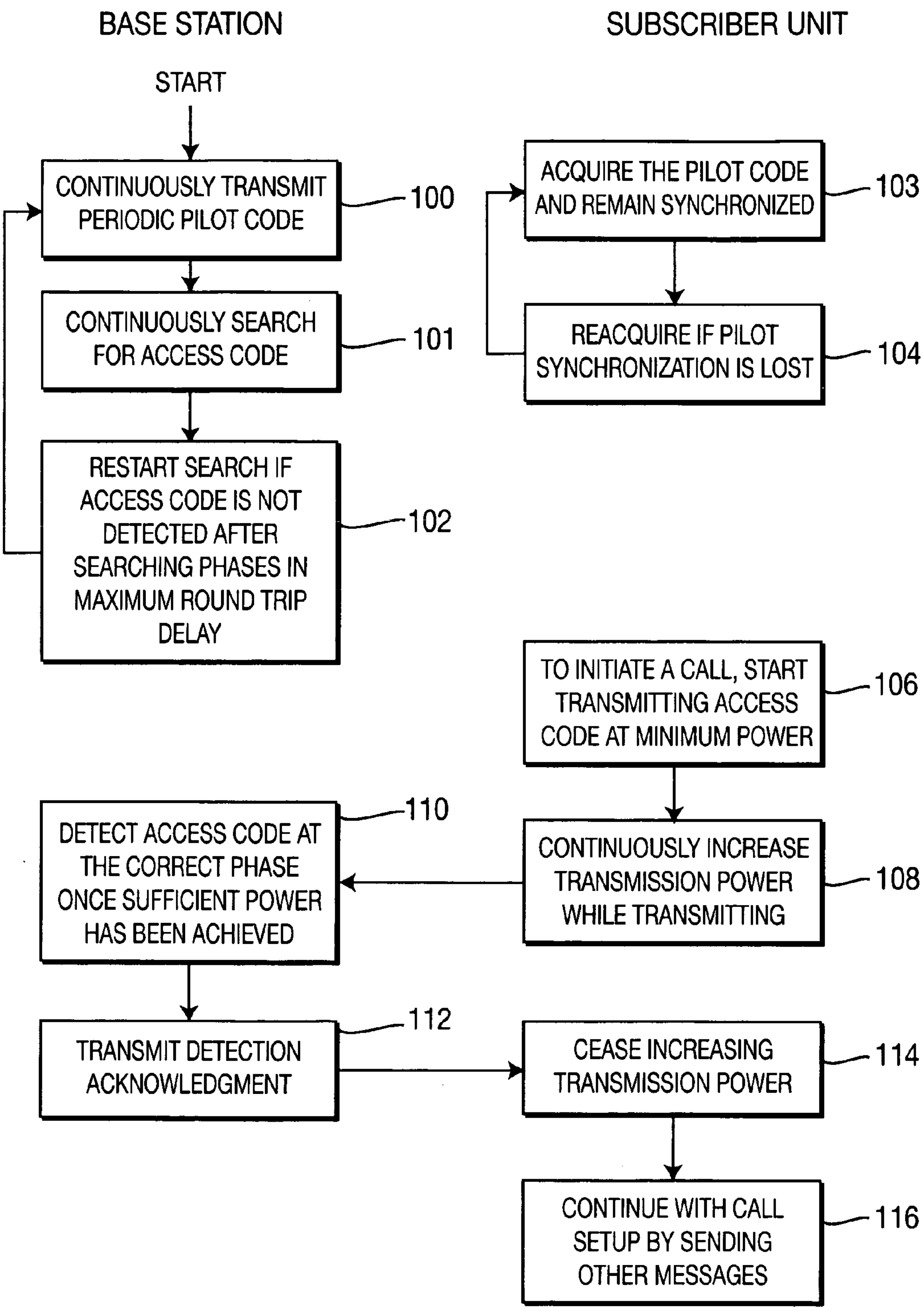
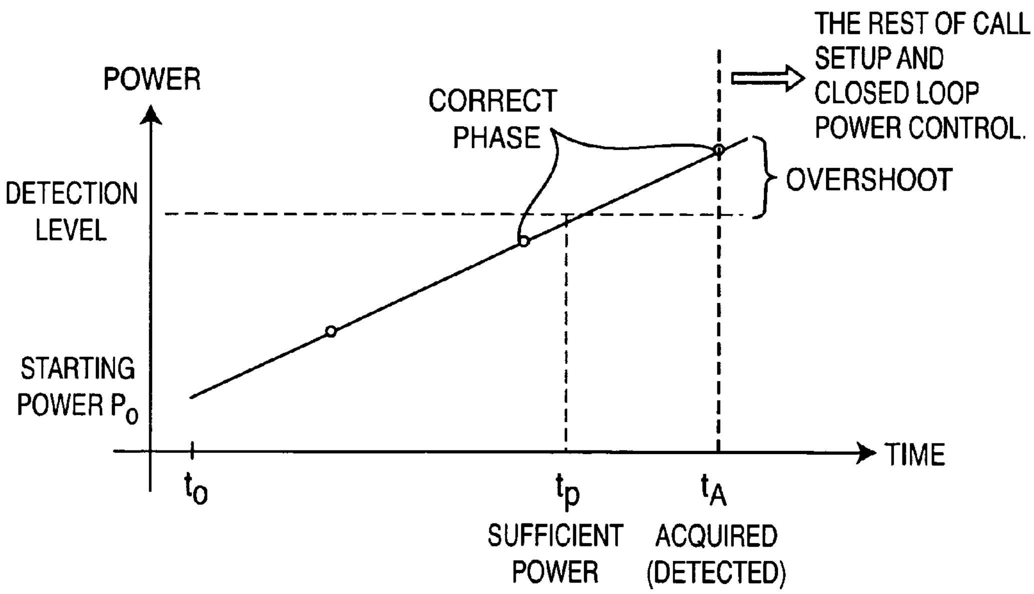
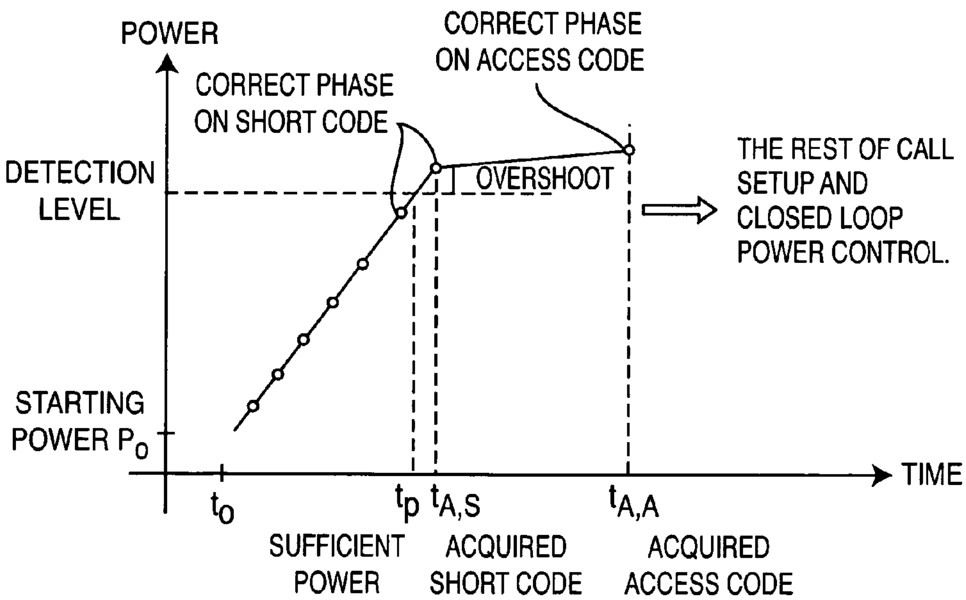

BASE STATION
SUBSCRIBER UNIT
START
CONTINUOUSLY TRANSMIT PERIODIC PILOT CODE
100
CONTINUOUSLY SEARCH FOR ACCESS CODE
101
RESTART SEARCH IF ACCESS CODE IS NOT DETECTED AFTER SEARCHING PHASES IN MAXIMUM ROUND TRIP DELAY
102
ACQUIRE THE PILOT CODE AND REMAIN SYNCHRONIZED
103
REACQUIRE IF PILOT SYNCHRONIZATION IS LOST
104
TO INITIATE A CALL, START TRANSMITTING ACCESS CODE AT MINIMUM POWER
106
CONTINUOUSLY INCREASE TRANSMISSION POWER WHILE TRANSMITTING
108
DETECT ACCESS CODE AT THE CORRECT PHASE ONCE SUFFICIENT POWER HAS BEEN ACHIEVED
110
TRANSMIT DETECTION ACKNOWLEDGMENT
112
CEASE INCREASING TRANSMISSION POWER
114
CONTINUE WITH CALL SETUP BY SENDING OTHER MESSAGES
116

FIG. 4



POWER
CORRECT PHASE
THE REST OF CALL SETUP AND CLOSED LOOP POWER CONTROL.
OVERSHOOT
DETECTION LEVEL
STARTING POWER P_0
TIME
t_0
t_P
t_A
SUFFICIENT POWER
ACQUIRED (DETECTED)

FIG. 5



POWER
CORRECT PHASE ON ACCESS CODE
CORRECT PHASE ON SHORT CODE
DETECTION LEVEL
OVERSHOOT
THE REST OF CALL SETUP AND CLOSED LOOP POWER CONTROL.
STARTING POWER P_0
TIME
t_0
t_P
$t_{A,S}$
$t_{A,A}$
SUFFICIENT POWER
ACQUIRED SHORT CODE
ACQUIRED ACCESS CODE

FIG. 7

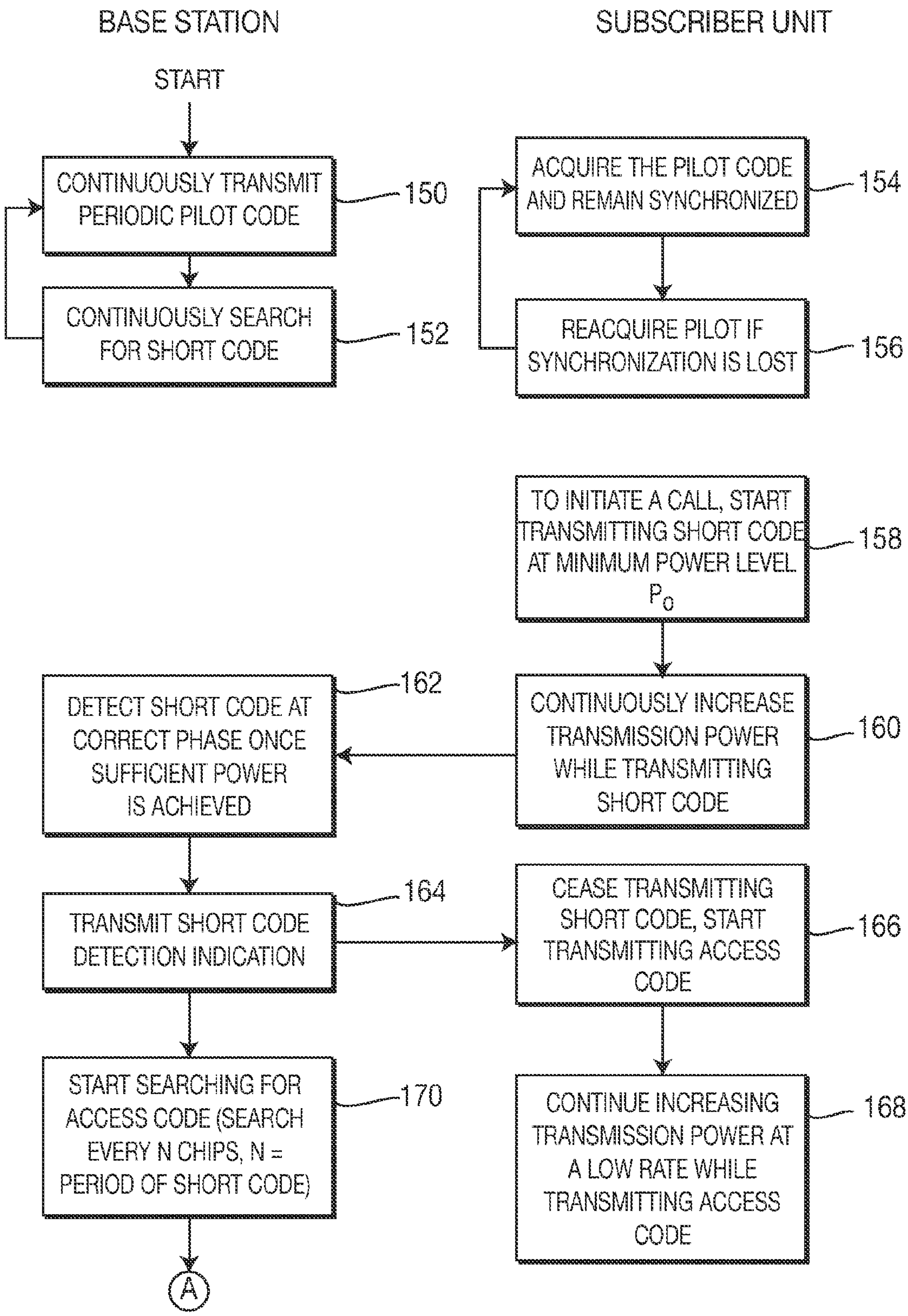

BASE STATION
SUBSCRIBER UNIT
START
CONTINUOUSLY TRANSMIT PERIODIC PILOT CODE
150
CONTINUOUSLY SEARCH FOR SHORT CODE
152
ACQUIRE THE PILOT CODE AND REMAIN SYNCHRONIZED
154
REACQUIRE PILOT IF SYNCHRONIZATION IS LOST
156
TO INITIATE A CALL, START TRANSMITTING SHORT CODE AT MINIMUM POWER LEVEL P_0
158
CONTINUOUSLY INCREASE TRANSMISSION POWER WHILE TRANSMITTING SHORT CODE
160
DETECT SHORT CODE AT CORRECT PHASE ONCE SUFFICIENT POWER IS ACHIEVED
162
TRANSMIT SHORT CODE DETECTION INDICATION
164
CEASE TRANSMITTING SHORT CODE, START TRANSMITTING ACCESS CODE
166
START SEARCHING FOR ACCESS CODE (SEARCH EVERY N CHIPS, N = PERIOD OF SHORT CODE)
170
CONTINUE INCREASING TRANSMISSION POWER AT A LOW RATE WHILE TRANSMITTING ACCESS CODE
168
A

FIG. 6A

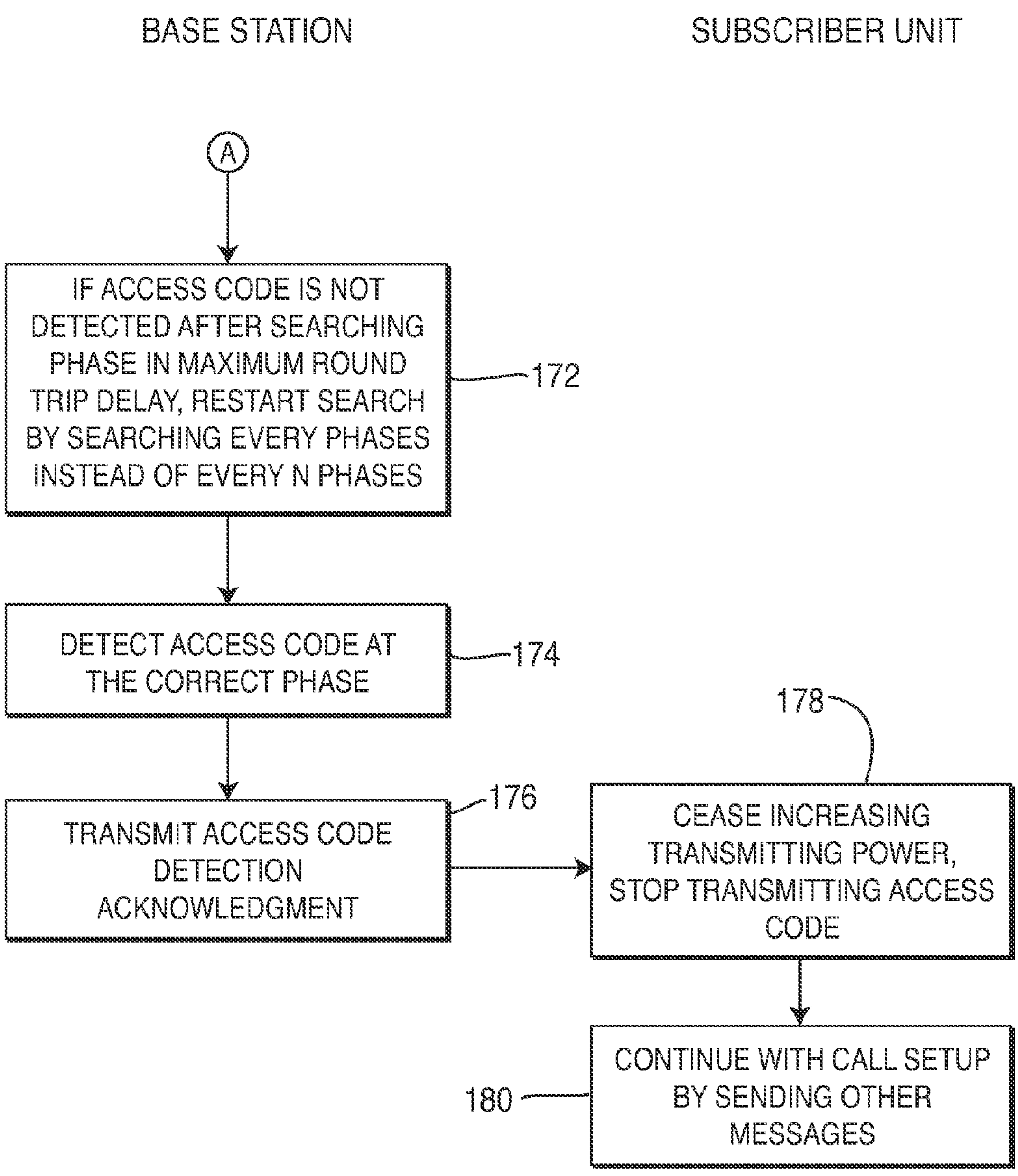

BASE STATION
SUBSCRIBER UNIT
A
IF ACCESS CODE IS NOT DETECTED AFTER SEARCHING PHASE IN MAXIMUM ROUND TRIP DELAY, RESTART SEARCH BY SEARCHING EVERY PHASES INSTEAD OF EVERY N PHASES
172
DETECT ACCESS CODE AT THE CORRECT PHASE
174
TRANSMIT ACCESS CODE DETECTION ACKNOWLEDGMENT
176
178
CEASE INCREASING TRANSMITTING POWER, STOP TRANSMITTING ACCESS CODE
180
CONTINUE WITH CALL SETUP BY SENDING OTHER MESSAGES

FIG. 6B

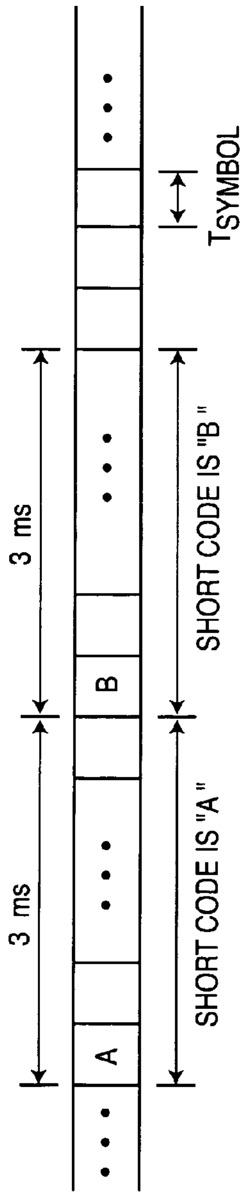

3 ms
3 ms
A
B
TSYMBOL
SHORT CODE IS "A"
SHORT CODE IS "B"

FIG. 8

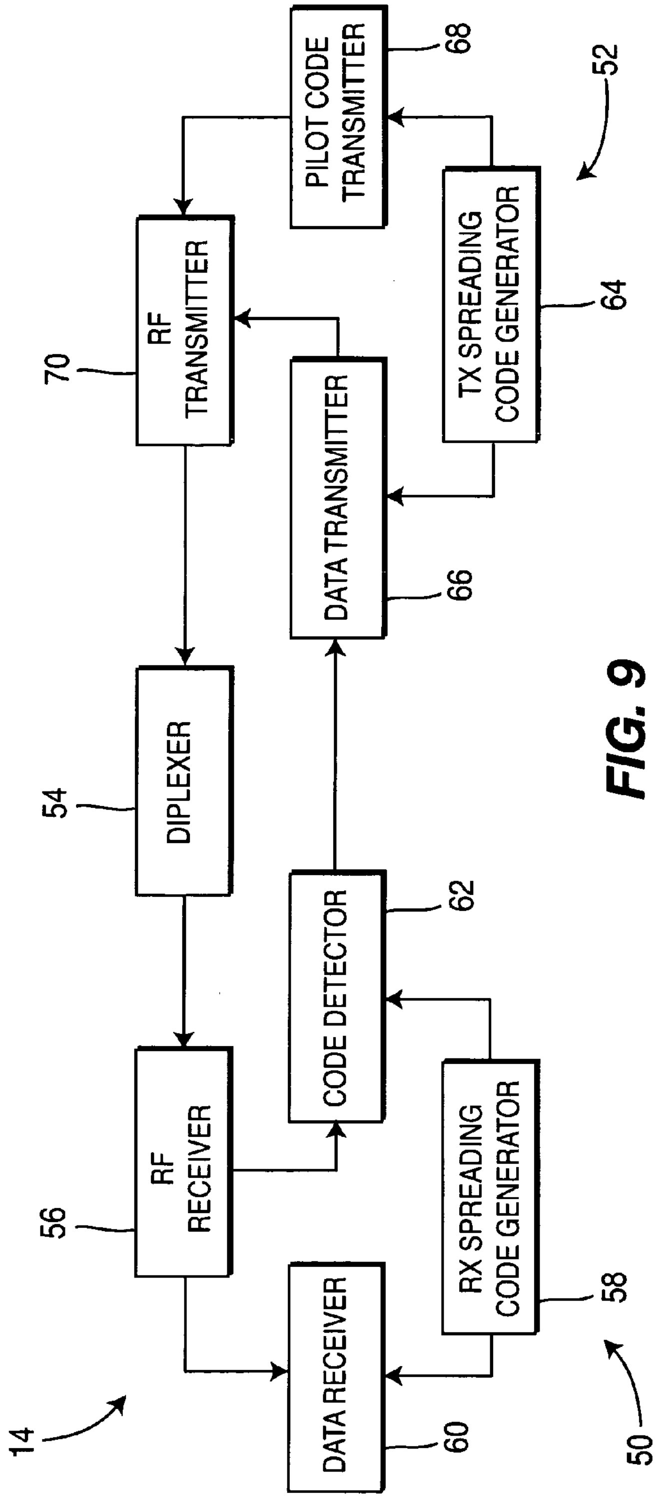

PILOT CODE TRANSMITTER
68
52
RF TRANSMITTER
70
TX SPREADING CODE GENERATOR
64
DATA TRANSMITTER
66
DIPLEXER
54
CODE DETECTOR
62
RF RECEIVER
56
RX SPREADING CODE GENERATOR
58
DATA RECEIVER
60
14
50

FIG. 9

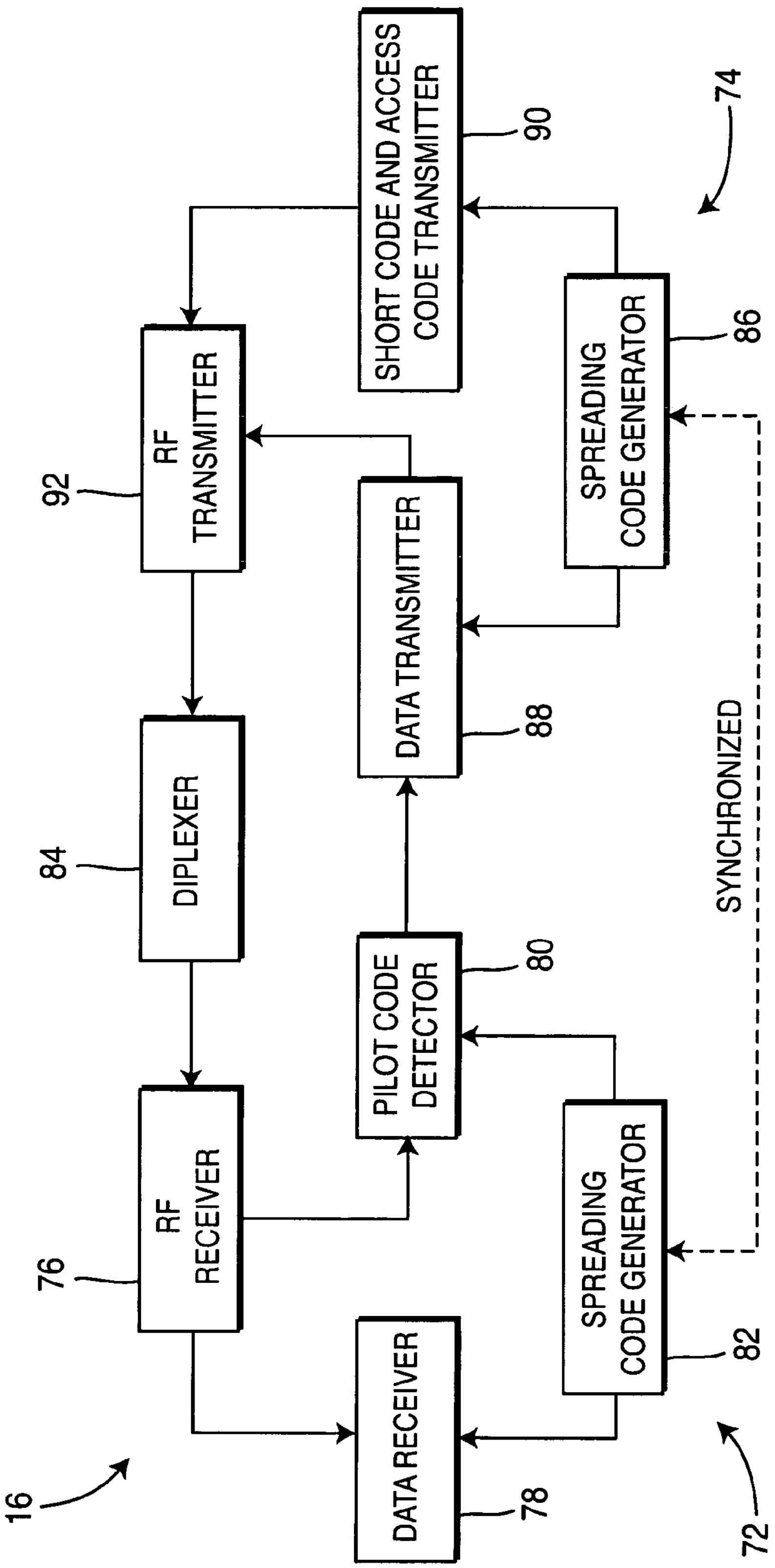

SHORT CODE AND ACCESS CODE TRANSMITTER
90
74
RF TRANSMITTER
92
SPREADING CODE GENERATOR
86
DATA TRANSMITTER
88
DIPLEXER
84
SYNCHRONIZED
PILOT CODE DETECTOR
80
RF RECEIVER
76
SPREADING CODE GENERATOR
82
DATA RECEIVER
78
16
72

FIG. 10

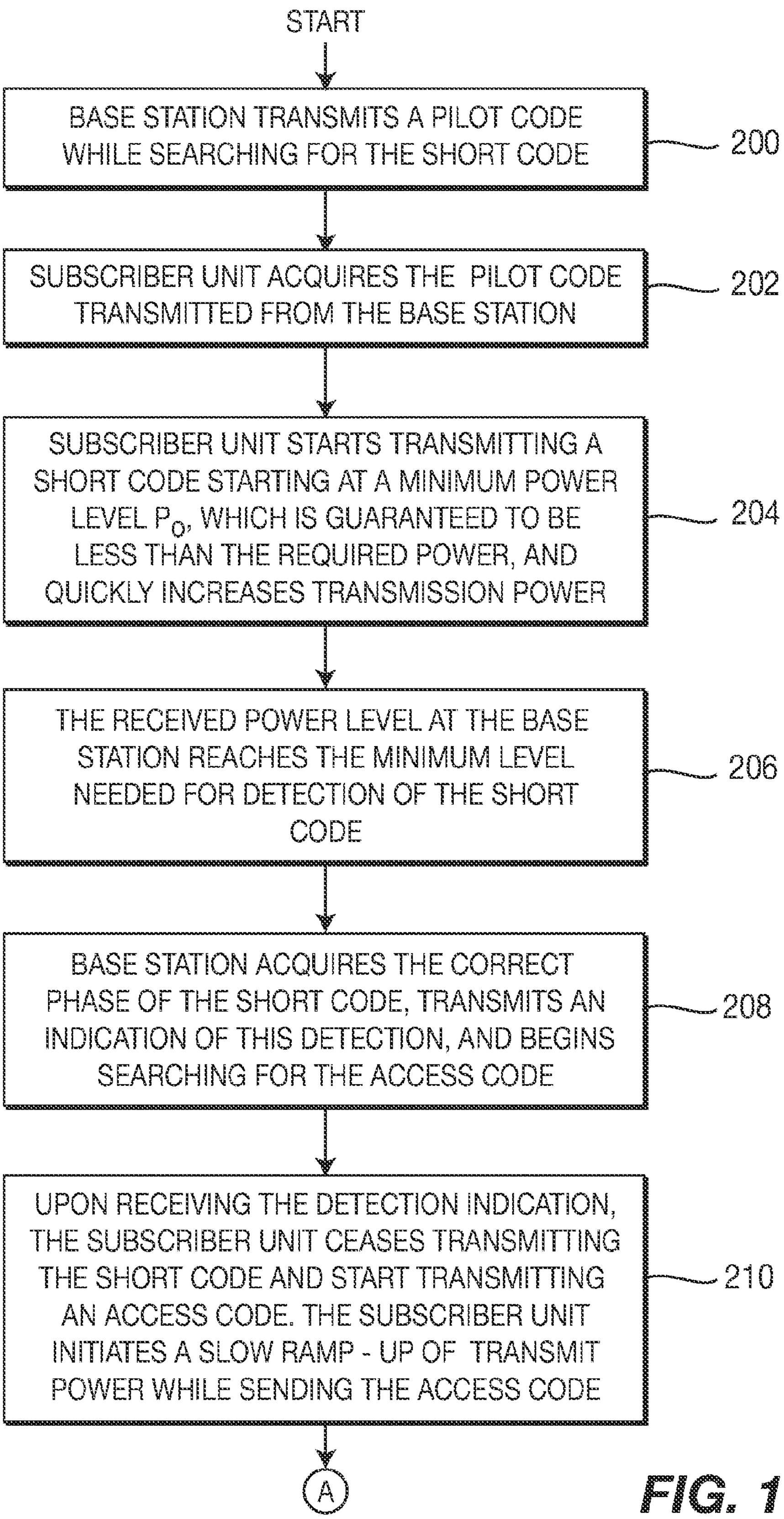

START
BASE STATION TRANSMITS A PILOT CODE WHILE SEARCHING FOR THE SHORT CODE
200
SUBSCRIBER UNIT ACQUIRES THE PILOT CODE TRANSMITTED FROM THE BASE STATION
202
SUBSCRIBER UNIT STARTS TRANSMITTING A SHORT CODE STARTING AT A MINIMUM POWER LEVEL P_0, WHICH IS GUARANTEED TO BE LESS THAN THE REQUIRED POWER, AND QUICKLY INCREASES TRANSMISSION POWER
204
THE RECEIVED POWER LEVEL AT THE BASE STATION REACHES THE MINIMUM LEVEL NEEDED FOR DETECTION OF THE SHORT CODE
206
BASE STATION ACQUIRES THE CORRECT PHASE OF THE SHORT CODE, TRANSMITS AN INDICATION OF THIS DETECTION, AND BEGINS SEARCHING FOR THE ACCESS CODE
208
UPON RECEIVING THE DETECTION INDICATION, THE SUBSCRIBER UNIT CEASES TRANSMITTING THE SHORT CODE AND START TRANSMITTING AN ACCESS CODE. THE SUBSCRIBER UNIT INITIATES A SLOW RAMP - UP OF TRANSMIT POWER WHILE SENDING THE ACCESS CODE
210
A

FIG. 11A

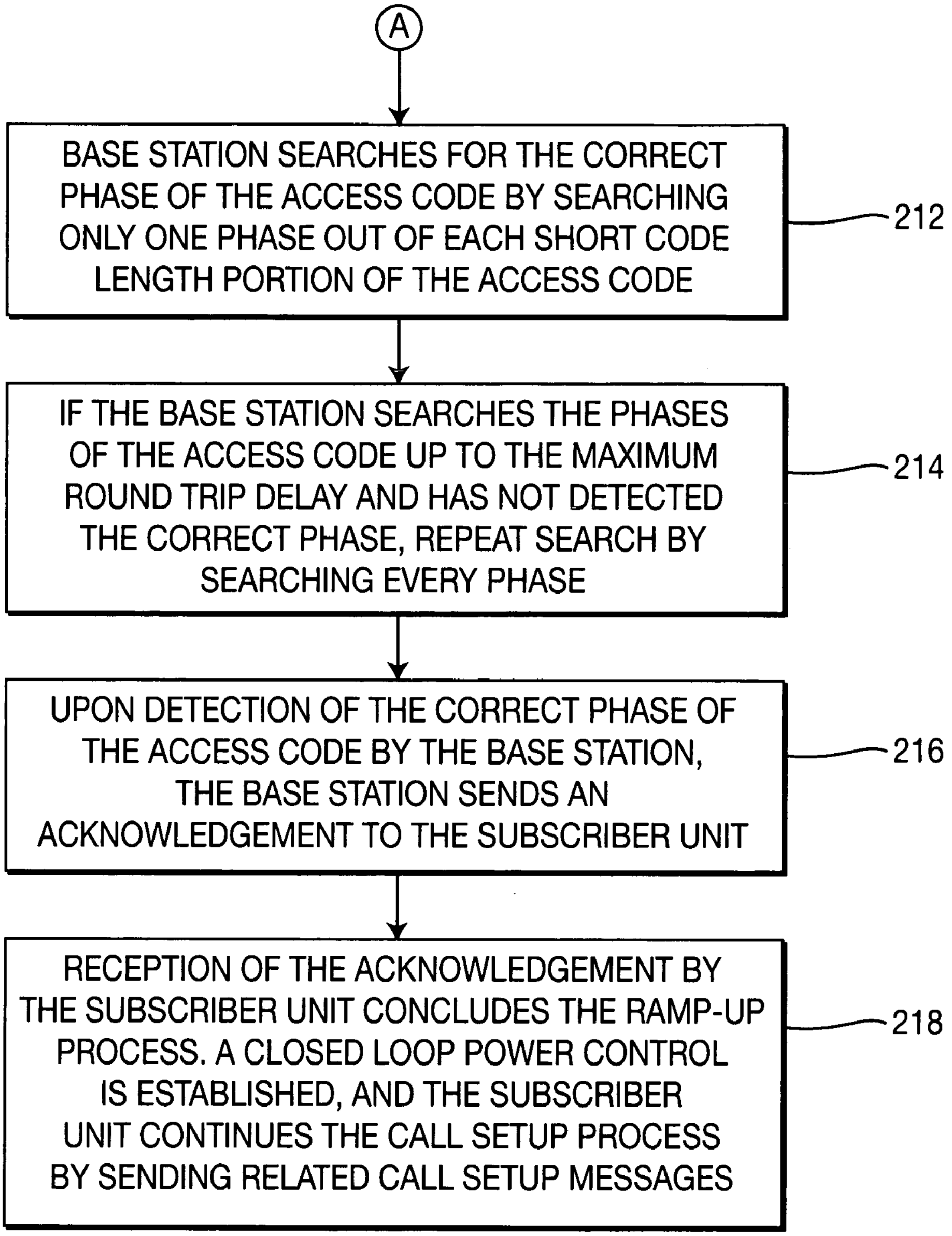

A
BASE STATION SEARCHES FOR THE CORRECT PHASE OF THE ACCESS CODE BY SEARCHING ONLY ONE PHASE OUT OF EACH SHORT CODE LENGTH PORTION OF THE ACCESS CODE
212
IF THE BASE STATION SEARCHES THE PHASES OF THE ACCESS CODE UP TO THE MAXIMUM ROUND TRIP DELAY AND HAS NOT DETECTED THE CORRECT PHASE, REPEAT SEARCH BY SEARCHING EVERY PHASE
214
UPON DETECTION OF THE CORRECT PHASE OF THE ACCESS CODE BY THE BASE STATION, THE BASE STATION SENDS AN ACKNOWLEDGEMENT TO THE SUBSCRIBER UNIT
216
RECEPTION OF THE ACKNOWLEDGEMENT BY THE SUBSCRIBER UNIT CONCLUDES THE RAMP-UP PROCESS. A CLOSED LOOP POWER CONTROL IS ESTABLISHED, AND THE SUBSCRIBER UNIT CONTINUES THE CALL SETUP PROCESS BY SENDING RELATED CALL SETUP MESSAGES
218

FIG. 11B

METHOD AND APPARATUS FOR PERFORMING AN ACCESS PROCEDURE

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation of application Ser. No. 10/866,851, filed Jun. 14, 2004 now U.S. Pat. No. 7,117,004, which is a continuation of application Ser. No. 10/400,343, filed Mar. 26, 2003, which issued on Jan. 4, 2005 as U.S. Pat. No. 6,839,567, which is a continuation of Ser. No. 10/086,320, filed Mar. 1, 2002, which issued on May 27, 2003 as U.S. Pat. No. 6,571,105; which is a continuation of application Ser. No. 09/721,034, filed Nov. 22, 2000, which issued on Dec. 10, 2002 as U.S. Pat. No. 6,493,563; which is a continuation of application Ser. No. 09/003,104, filed Jan. 6, 1998, which issued on Jan. 30, 2001 as U.S. Pat. No. 6,181,949; which is a continuation of application Ser. No. 08/670,162, filed on Jun. 27, 1996, which issued on Nov. 24, 1998 as U.S. Pat. No. 5,841,768; which applications and patents are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to CDMA communication systems. More specifically, the present invention relates to a CDMA communication system which utilizes the transmission of short codes from subscriber units to a base station to reduce the time required for the base station to detect the signal from a subscriber unit. The improved detection time allows a faster ramp-up of the initial transmit power from the subscriber units while reducing the unnecessary power overshoot.

2. Description of Related Art

The use of wireless telecommunication systems has grown dramatically in the last decade as the reliability and capacity of the systems have improved. Wireless communication systems are being utilized in a variety of applications where land line based systems are impractical or impossible to use. Applications of wireless communications include cellular phone communications, communications in remote locations, and temporary communications for disaster recovery. Wireless communication systems have also become an economically viable alternative to replacing aging telephone lines and outdated telephone equipment.

The portion of the RF spectrum available for use by wireless communication systems is a critical resource. The RF spectrum must be shared among all commercial, governmental and military applications. There is a constant desire to improve the efficiency of wireless communication systems in order to increase system capacity.

Code division multiple access (CDMA) wireless communication systems have shown particular promise in this area. Although more traditional time division multiple access (TDMA) and frequency division multiple access (FDMA) systems have improved using the latest technological advances, CDMA systems, in particular Broadband Code Division Multiple Access™ (B-CDMA™) systems, have significant advantages over TDMA and FDMA systems. This efficiency is due to the improved coding and modulation density, interference rejection and multipath tolerance of B-CDMA™ systems, as well as reuse of the same spectrum in every communication cell. The format of CDMA communication signals also makes it extremely difficult to intercept calls, thereby ensuring greater privacy for callers and providing greater immunity against fraud.

In a CDMA system, the same portion of the frequency spectrum is used for communication by all subscriber units. Each subscriber unit's baseband data signal is multiplied by a code sequence, called the "spreading code", which has a much higher rate than the data. The ratio of the spreading code rate to the data symbol rate is called the "spreading factor" or the "processing gain". This coding results in a much wider transmission spectrum than the spectrum of the baseband data signal, hence the technique is called "spread spectrum". Subscriber units and their communications can be discriminated by assigning a unique spreading code to each communication link which is called a CDMA channel. Since all communications are sent over the same frequency band, each CDMA communication overlaps communications from other subscriber units and noise-related signals in both frequency and time.

The use of the same frequency spectrum by a plurality of subscriber units increases the efficiency of the system. However, it also causes a gradual degradation of the performance of the system as the number of users increase. Each subscriber unit detects communication signals with its unique spreading code as valid signals and all other signals are viewed as noise. The stronger the signal from a subscriber unit arrives at the base station, the more interference the base station experiences when receiving and demodulating signals from other subscriber units. Ultimately, the power from one subscriber unit may be great enough to terminate communications of other subscriber units. Accordingly, it is extremely important in wireless CDMA communication systems to control the transmission power of all subscriber units. This is best accomplished by using a closed loop power control algorithm once a communication link is established. A detailed explanation of such a closed loop algorithm is disclosed in U.S. Patent Application entitled Code Division Multiple Access (CDMA) System and Method filed concurrently herewith, which is incorporated by reference as if fully set forth.

The control of transmission power is particularly critical when a subscriber unit is attempting to initiate communications with a base station and a power control loop has not yet been established. Typically, the transmission power required from a subscriber unit changes continuously as a function of the propagation loss, interference from other subscribers, channel noise, fading and other channel characteristics. Therefore, a subscriber unit does not know the power level at which it should start transmitting. If the subscriber unit begins transmitting at a power level that is too high, it may interfere with the communications of other subscriber units and may even terminate the communications of other subscriber units. If the initial transmission power level is too low, the subscriber unit will not be detected by the base station and a communication link will not be established.

There are many methods for controlling transmission power in a CDMA communication system. For example, U.S. Pat. No. 5,056,109 (Gilhousen et al.) discloses a transmission power control system wherein the transmission power of the subscriber unit is based upon periodic signal measurements from both the subscriber unit and the base station. The base station transmits a pilot signal to all subscriber units which analyze the received pilot signal, estimate the power loss in the transmitted signal and adjust their transmission power accordingly. Each subscriber unit includes a non-linear loss output filter which prevents sudden increases in power which would cause interference to other subscriber units. This method is too complex to permit a base station to quickly acquire a subscriber unit while limiting the interference to other subscriber units. In addi-

tion, the propagation losses, interference and noise levels experienced in a forward link (transmission from the base station to a subscriber unit) is often not the same as in a reverse link (transmission from a subscriber unit to the base station). Reverse link power estimates based on forward link losses are not precise.

Many other types of prior art transmission power control systems require complex control signaling between communicating units or preselected transmission values to control transmission power. These power control techniques are inflexible and often impractical to implement.

Accordingly, there is a need for an efficient method of controlling the initial ramp-up of transmission power by subscriber units in a wireless CDMA communication system.

SUMMARY OF THE INVENTION

The present invention comprises a novel method of controlling transmission power during the establishment of a channel in a CDMA communication system by utilizing the transmission of a short code from a subscriber unit to a base station during initial power ramp-up. The short code is a sequence for detection by the base station which has a much shorter period than a conventional spreading code. The ramp-up starts from a power level that is guaranteed to be lower than the required power level for detection by the base station. The subscriber unit quickly increases transmission power while repeatedly transmitting the short code until the signal is detected by the base station. Once the base station detects the short code, it sends an indication to the subscriber unit to cease increasing transmission power. The use of short codes limits power overshoot and interference to other subscriber stations and permits the base station to quickly synchronize to the spreading code used by the subscriber unit.

Accordingly, it is an object of the present invention to provide an improved technique for controlling power ramp-up during establishment of a communication channel between a CDMA subscriber unit and base station.

Other objects and advantages of the present invention will become apparent after reading the description of a presently preferred embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic overview of a code division multiple access communication system in accordance with the present invention;

FIG. **2** is a diagram showing the operating range of a base station;

FIG. **3** is a timing diagram of communication signals between a base station and a subscriber unit;

FIG. **4** is a flow diagram of the establishment of a communication channel between a base station and a subscriber unit;

FIG. **5** is a graph of the transmission power output from a subscriber unit;

FIGS. **6**A and **6**B are flow diagrams of the establishment of a communication channel between a base station and a subscriber unit in accordance with the preferred embodiment of the present invention using short codes;

FIG. **7** is a graph of the transmission power output from a subscriber unit using short codes;

FIG. **8** shows the adaptive selection of short codes;

FIG. **9** is a block diagram of a base station in accordance with the present invention;

FIG. **10** is a block diagram of the subscriber unit in accordance with the present invention; and

FIGS. **11**A and **11**B are flow diagrams of the ramp-up procedure implemented in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred embodiment will be described with reference to the drawing figures where identical numerals represent similar elements throughout.

A communication network **10** embodying the present invention is shown in FIG. **1**. The communication network **10** generally comprises one or more base stations **14**, each of which is in wireless communication with a plurality of subscriber units **16**, which may be fixed or mobile. Each subscriber unit **16** communicates with either the closest base station **14** or the base station **14** which provides the strongest communication signal. The base stations **14** also communicate with a base station controller **20**, which coordinates communications among base stations **14**. The communication network **10** may also be connected to a public switched telephone network (PSTN) **22**, wherein the base station controller **20** also coordinates communications between the base stations **14** and the PSTN **22**. Preferably, each base station **14** communicates with the base station controller **20** over a wireless link, although a land line may also be provided. A land line is particularly applicable when a base station **14** is in close proximity to the base station controller **20**.

The base station controller **20** performs several functions. Primarily, the base station controller **20** provides all of the operations, administrative and maintenance (OA&M) signaling associated with establishing and maintaining all of the wireless communications between the subscriber units **16**, the base stations **14**, and the base station controller **20**. The base station controller **20** also provides an interface between the wireless communication system **10** and the PSTN **22**. This interface includes multiplexing and demultiplexing of the communication signals that enter and leave the system **10** via the base station controller **20**. Although the wireless communication system **10** is shown employing antennas to transmit RF signals, one skilled in the art should recognize that communications may be accomplished via microwave or satellite uplinks. Additionally, the functions of the base station controller **20** may be combined with a base station **14** to form a "master base station".

Referring to FIG. **2**, the propagation of signals between a base station **14** and a plurality of subscriber units **16** is shown. A two-way communication channel (link) **18** comprises a signal transmitted **21** (Tx) from the base station **14** to the subscriber unit **16** and a signal received **23** (Rx) by the base station **14** from the subscriber unit **16**. The Tx signal **21** is transmitted from the base station **14** and is received by the subscriber unit **16** after a propagation delay Δt. Similarly, the Rx signal originates at the subscriber unit **16** and terminates at the base station **14** after a further propagation delay Δt. Accordingly, the round trip propagation delay is $2\Delta t$. In the preferred embodiment, the base station **14** has an operating range of approximately 30 kilometers. The round trip propagation delay **24** associated with a subscriber unit **16** at the maximum operating range is 200 microseconds.

It should be apparent to those of skill in the art that the establishment of a communication channel between a base station and a subscriber unit is a complex procedure involving many tasks performed by the base station and the

subscriber unit which are outside the scope of the present invention. The present invention is directed to initial power ramp-up and synchronization during the establishment of a communication channel.

Referring to FIG. **3**, the signaling between a base station **14** and a subscriber unit **16** is shown. In accordance with the present invention, the base station **14** continuously transmits a pilot code **40** to all of the subscriber units **16** located within the transmitting range of the base station **14**. The pilot code **40** is a spreading code which carries no data bits. The pilot code **40** is used for subscriber unit **16** acquisition and synchronization, as well as for determining the parameters of the adaptive matched filter used in the receiver.

The subscriber unit **16** must acquire the pilot code **40** transmitted by the base station **14** before it can receive or transmit any data. Acquisition is the process whereby the subscriber unit **16** aligns its locally generated spreading code with the received pilot code **40**. The subscriber unit **16** searches through all of the possible phases of the received pilot code **40** until it detects the correct phase, (the beginning of the pilot code **40**).

The subscriber unit **16** then synchronizes its transmit spreading code to the received pilot code **40** by aligning the beginning of its transmit spreading code to the beginning of the pilot code **40**. One implication of this receive and transmit synchronization is that the subscriber unit **16** introduces no additional delay as far as the phase of the spreading codes are concerned. Accordingly, as shown in FIG. **3**, the relative delay between the pilot code **40** transmitted from the base station **14** and the subscriber unit's transmit spreading code **42** received at the base station **14** is $2\Delta t$, which is solely due to the round trip propagation delay.

In the preferred embodiment, the pilot code is 29,877,120 chips in length and takes approximately 2 to 5 seconds to transmit, depending on the spreading factor. The length of the pilot code **40** was chosen to be a multiple of the data symbol no matter what kind of data rate or bandwidth is used. As is well known by those of skill in the art, a longer pilot code **40** has better randomness properties and the frequency response of the pilot code **40** is more uniform. Additionally, a longer pilot code **40** provides low channel cross correlation, thus increasing the capacity of the system **10** to support more subscriber units **16** with less interference. The use of a long pilot code **40** also supports a greater number of random short codes. For synchronization purposes, the pilot code **40** is chosen to have the same period as all of the other spreading codes used by the system **10**. Thus, once a subscriber unit **16** acquires the pilot code **40**, it is synchronized to all other signals transmitted from the base station **14**.

During idle periods, when a call is not in progress or pending, the subscriber unit **16** remains synchronized to the base station **14** by periodically reacquiring the pilot code **40**. This is necessary for the subscriber unit **16** to receive and demodulate any downlink transmissions, in particular paging messages which indicate incoming calls.

When a communication link is desired, the base station **14** must acquire the signal transmitted from the subscriber unit **16** before it can demodulate the data. The subscriber unit **16** must transmit an uplink signal for acquisition by the base station **14** to begin establishing the two-way communication link. A critical parameter in this procedure is the transmission power level of the subscriber unit **16**. A transmission power level that is too high can impair communications in the whole service area, whereas a transmission power level that is too low can prevent the base station **14** from detecting the uplink signal.

In a first embodiment of the present invention the subscriber unit **16** starts transmitting at a power level guaranteed to be lower than what is required and increases transmission power output until the correct power level is achieved. This avoids sudden introduction of a strong interference, hence improving system **10** capacity.

The establishment of a communication channel in accordance with the present invention and the tasks performed by the base station **14** and a subscriber unit **16** are shown in FIG. **4**. Although many subscriber units **16** may be located within the operating range of the base station **14**, reference will be made hereinafter to a single subscriber unit **16** for simplicity in explaining the operation of the present invention.

The base station **14** begins by continuously transmitting a periodic pilot code **40** to all subscriber units **16** located within the operating range of the base station **14** (step **100**). As the base station **14** transmits the pilot code **40** (step **100**), the base station **14** searches (step **101**) for an "access code" **42** transmitted by a subscriber unit **16**. The access code **42** is a known spreading code transmitted from a subscriber unit **16** to the base station **14** during initiation of communications and power ramp-up. The base station **14** must search through all possible phases (time shifts) of the access code **42** transmitted from the subscriber unit **16** in order to find the correct phase. This is called the "acquisition" or the "detection" process (step **101**). The longer the access code **42**, the longer it takes for the base station **14** to search through the phases and acquire the correct phase.

As previously explained, the relative delay between signals transmitted from the base station **14** and return signals received at the base station **14** corresponds to the round trip propagation delay $2\Delta t$. The maximum delay occurs at the maximum operating range of the base station **14**, known as the cell boundary. Accordingly, the base station **14** must search up to as many code phases as there are in the maximum round trip propagation delay, which is typically less code phases than there are in a code period.

For a data rate Rb and spreading code rate Rc, the ratio $L=Rc/Rb$ is called the spreading factor or the processing gain. In the preferred embodiment of the present invention, the cell boundary radius is 30 km, which corresponds to approximately between 1000 and 2500 code phases in the maximum round trip delay, depending on the processing gain.

If the base station **14** has not detected the access code after searching through the code phases corresponding to the maximum round trip delay the search is repeated starting from the phase of the pilot code **40** which corresponds to zero delay (step **102**).

During idle periods, the pilot code **40** from the base station **14** is received at the subscriber unit **16** which periodically synchronizes its transmit spreading code generator thereto (step **103**). If synchronization with the pilot code **40** is lost, the subscriber unit **16** reacquires the pilot code **40** and resynchronizes (step **104**).

When it is desired to initiate a communication link, the subscriber unit **16** starts transmitting the access code **42** back to the base station **14** (step **106**). The subscriber unit **16** continuously increases the transmission power while retransmitting the access code **42** (step **108**) until it receives an acknowledgment from the base station **14**. The base station **14** detects the access code **42** at the correct phase once the minimum power level for reception has been achieved (step **110**). The base station **14** subsequently transmits an access code detection acknowledgment signal (step **112**) to the subscriber unit **16**. Upon receiving the acknowl-

edgment, the subscriber unit ceases the transmission power increase (step **114**). With the power ramp-up completed, closed loop power control and call setup signaling is performed (step **116**) to establish the two-way communication link.

Although this embodiment limits subscriber unit **16** transmission power, acquisition of the subscriber unit **16** by the base station **14** in this manner may lead to unnecessary power overshoot from the subscriber unit **16**, thereby reducing the performance of the system **10**.

The transmission power output profile of the subscriber unit **16** is shown in FIG. **5**. At t_0, the subscriber unit **16** starts transmitting at the starting transmission power level P_0, which is a power level guaranteed to be less than the power level required for detection by the base station **14**. The subscriber unit **16** continually increases the transmission power level until it receives the detection indication from the base station **14**. For the base station **14** to properly detect the access code **42** from the subscriber unit **16** the access code **42** must: 1) be received at a sufficient power level; and 2) be detected at the proper phase. Accordingly, referring to FIG. **5**, although the access code **42** is at a sufficient power level for detection by the base station **14** at t_P, the base station **14** must continue searching for the correct phase of the access code **42** which occurs at t_A.

Since the subscriber unit **16** continues to increase the output transmission power level until it receives the detection indication from the base station **14**, the transmission power of the access code **42** exceeds the power level required for detection by the base station **14**. This causes unnecessary interference to all other subscriber units **16**. If the power overshoot is too large, the interference to other subscriber units **16** may be so severe as to terminate ongoing communications of other subscriber units **16**.

The rate that the subscriber unit **16** increases transmission power to avoid overshoot may be reduced, however, this results in a longer call setup time. Those of skill in the art would appreciate that adaptive ramp-up rates can also be used, yet these rates have shortcomings and will not appreciably eliminate power overshoot in all situations.

The preferred embodiment of the present invention utilizes "short codes" and a two-stage communication link establishment procedure to achieve fast power ramp-up without large power overshoots. The spreading code transmitted by the subscriber unit **16** is much shorter than the rest of the spreading codes (hence the term short code), so that the number of phases is limited and the base station **14** can quickly search through the code. The short code used for this purpose carries no data.

The tasks performed by the base station **14** and the subscriber unit **16** to establish a communication channel using short codes in accordance with the preferred embodiment of the present invention are shown in FIGS. **6**A and **6**B. During idle periods, the base station **14** periodically and continuously transmits the pilot code to all subscriber units **16** located within the operating range of the base station **14** (step **150**). The base station **14** also continuously searches for a short code transmitted by the subscriber unit **16** (step **152**). The subscriber unit **16** acquires the pilot code and synchronizes its transmit spreading code generator to the pilot code (step **154**). The subscriber unit **16** also periodically checks to ensure it is synchronized. If synchronization is lost, the subscriber unit **16** reacquires the pilot signal transmitted by the base station (step **156**).

When a communication link is desired, the subscriber unit **16** starts transmitting a short code at the minimum power level P_0 (step **158**) and continuously increases the transmission power level while retransmitting the short code (step **160**) until it receives an acknowledgment from the base station **14** that the short code has been detected by the base station **14**.

The access code in the preferred embodiment, as previously described herein, is approximately 30 million chips in length. However, the short code is much smaller. The short code can be chosen to be any length that is sufficiently short to permit quick detection. There is an advantage in choosing a short code length such that it divides the access code period evenly. For the access code described herein, the short code is preferably chosen to be 32, 64 or 128 chips in length. Alternatively, the short code may be as short as one symbol length, as will be described in detail hereinafter.

Since the start of the short code and the start of the access code are synchronized, once the base station **14** acquires the short code, the base station **14** knows that the corresponding phase of the access code is an integer multiple of N chips from the phase of the short code where N is the length of the short code. Accordingly, the base station **14** does not have to search all possible phases corresponding to the maximum round trip propagation delay.

Using the short code, the correct phase for detection by the base station **14** occurs much more frequently. When the minimum power level for reception has been achieved, the short code is quickly detected (step **162**) and the transmission power overshoot is limited. The transmission power ramp-up rate may be significantly increased without concern for a large power overshoot. In the preferred embodiment of the present invention, the power ramp-up rate using the short code is 1 dB per millisecond.

The base station **14** subsequently transmits a short code detection indication signal (step **164**) to the subscriber unit **16** which enters the second stage of the power ramp-up upon receiving this indication. In this stage, the subscriber unit **16** ceases transmitting the short code (step **166**) and starts continuously transmitting a periodic access code (step **166**). The subscriber unit **16** continues to ramp-up its transmission power while transmitting the access code, however the ramp-up rate is now much lower than the previous ramp-up rate used with the short code (step **168**). The ramp-up rate with the access code is preferably 0.05 dB per millisecond. The slow ramp-up avoids losing synchronization with the base station **14** due to small changes in channel propagation characteristics.

At this point, the base station **14** has detected the short code at the proper phase and power level (step **162**). The base station **14** must now synchronize to the access code which is the same length as all other spreading codes and much longer than the short code. Utilizing the short code, the base station **14** is able to detect the proper phase of the access code much more quickly. The base station **14** begins searching for the proper phase of the access code (step **170**). However, since the start of the access code is synchronized with the start of the short code, the base station **14** is only required to search every N chips; where N=the length of the short code. In summary, the base station **14** quickly acquires the access code of the proper phase and power level by: 1) detecting the short code; and 2) determining the proper phase of the access code by searching every N chips of the access code from the beginning of the short code.

If the proper phase of the access code has not been detected after searching the number of phases in the maximum round trip delay the base station **14** restarts the search for the access code by searching every chip instead of every N chips (step **172**). When the proper phase of the access code has been detected (step **174**) the base station **14**

transmits an access code detection acknowledgment (step **176**) to the subscriber unit **16** which ceases the transmission power increase (step **178**) upon receiving this acknowledgment. With the power ramp-up completed, closed loop power control and call setup signaling is performed (step **180**) to establish the two-way communication link.

Referring to FIG. **7**, although the starting power level P_0 is the same as in the prior embodiment, the subscriber unit **16** may ramp-up the transmission power level at a much higher rate by using a short code. The short code is quickly detected after the transmission power level surpasses the minimum detection level, thus minimizing the amount of transmission power overshoot.

Although the same short code may be reused by the subscriber unit **16**, in the preferred embodiment of the present invention the short codes are dynamically selected and updated in accordance with the following procedure. Referring to FIG. **8**, the period of the short code is equal to one symbol length and the start of each period is aligned with a symbol boundary. The short codes are generated from a regular length spreading code. A symbol length portion from the beginning of the spreading code is stored and used as the short code for the next 3 milliseconds. Every 3 milliseconds, a new symbol length portion of the spreading code replaces the old short code. Since the spreading code period is an integer multiple of 3 milliseconds, the same short codes are repeated once every period of the spreading code.

Periodic updating of the short code averages the interference created by the short code over the entire spectrum. A detailed description of the selection and updating of the short codes is outside the scope of this invention. However, such a detailed description is disclosed in the related application U.S. Patent Appln. entitled Code Division Multiple Access (CDMA) System and Method.

A block diagram of the base station **14** is shown in FIG. **9**. Briefly described, the base station **14** comprises a receiver section **50**, a transmitter section **52** and a diplexer **54**. An RF receiver **56** receives and down-converts the RF signal received from the diplexer **54**. The receive spreading code generator **58** outputs a spreading code to both the data receiver **60** and the code detector **62**. In the data receiver **60**, the spreading code is correlated with the baseband signal to extract the data signal which is forwarded for further processing. The received baseband signal is also forwarded to the code detector **62** which detects the access code or the short code from the subscriber unit **16** and adjusts the timing of the spreading code generator **58** to establish a communication channel **18**.

In the transmitter section **52** of the base station **14**, the transmit spreading code generator **64** outputs a spreading code to the data transmitter **66** and the pilot code transmitter **68**. The pilot code transmitter **68** continuously transmits the periodic pilot code. The data transmitter **66** transmits the short code detect indication and access code detect acknowledgment after the code detector **62** has detected the short code or the access code respectively. The data transmitter also sends other message and data signals. The signals from the data transmitter **66** and the pilot code transmitter **68** are combined and up-converted by the RF transmitter **70** for transmission to the subscriber units **16**.

A block diagram of the subscriber unit **16** is shown in FIG. **10**. Briefly described, the subscriber unit **16** comprises a receiver section **72**, a transmitter section **74** and a diplexer **84**. An RF receiver **76** receives and down-converts the RF signal received from the diplexer **84**. A pilot code detector **80** correlates the spreading code with the baseband signal to acquire the pilot code transmitted by the base station **14**. In this manner, the pilot code detector **80** maintains synchronization with the pilot code. The receiver spreading code generator **82** generates and outputs a spreading code to the data receiver **78** and the pilot code detector **80**. The data receiver **78** correlates the spreading code with the baseband signal to process the short code detect indication and the access code detect acknowledgment transmitted by the base station **14**.

The transmitter section **74** comprises a spreading code generator **86** which generates and outputs spreading codes to a data transmitter **88** and a short code and access code transmitter **90**. The short code and access code transmitter **90** transmits these codes at different stages of the power ramp-up procedure as hereinbefore described. The signals output by the data transmitter **88** and the short code and access code transmitter **90** are combined and up-converted by the RF transmitter **92** for transmission to the base station **14**. The timing of the receiver spreading code generator **82** is adjusted by the pilot code detector **80** through the acquisition process. The receiver and transmitter spreading code generators **82**, **86** are also synchronized.

An overview of the ramp-up procedure in accordance with the preferred current invention is summarized in FIGS. **11**A and **11**B. The base station **14** transmits a pilot code while searching for the short code (step **200**). The subscriber unit **16** acquires the pilot code transmitted from the base station **14** (step **202**), starts transmitting a short code starting at a minimum power level P_0 which is guaranteed to be less than the required power, and quickly increases transmission power (step **204**). Once the received power level at the base station **14** reaches the minimum level needed for detection of the short code (step **206**) the base station **14** acquires the correct phase of the short code, transmits an indication of this detection, and begins searching for the access code (step **208**). Upon receiving the detection indication, the subscriber unit **16** ceases transmitting the short code and starts transmitting an access code. The subscriber unit **16** initiates a slow ramp-up of transmit power while sending the access code (step **210**). The base station **14** searches for the correct phase of the access code by searching only one phase out of each short code length portion of the access code (step **212**). If the base station **14** searches the phases of the access code up to the maximum round trip delay and has not detected the correct phase, the search is repeated by searching every phase (step **214**). Upon detection of the correct phase of the access code by the base station **14**, the base station **14** sends an acknowledgment to the subscriber unit **16** (step **216**). Reception of the acknowledgment by the subscriber unit **16** concludes the ramp-up process. A closed loop power control is established, and the subscriber unit **16** continues the call setup process by sending related call setup messages (step **218**).

Although the invention has been described in part by making detailed reference to the preferred embodiment, such detail is intended to be instructive rather than restrictive. It will be appreciated by those skilled in the art that many variations may be made in the structure and mode of operation without departing from the spirit and scope of the invention as disclosed in the teachings herein.

What is claimed is:

1. A wireless code division multiple access (CDMA) subscriber unit comprising:

a transmitter configured such that, when the subscriber unit is first accessing a CDMA network and wants to establish communications with a base station associated with the network over a communication channel to

be indicated by the base station, the transmitter successively transmits signals until the subscriber unit receives from the base station an indication that a transmitted one of the signals has been detected by the base station, wherein each transmission of one of the signals by the transmitter is at an increased power level with respect to a prior transmission of one of the signals;

the transmitter further configured such that the transmitter transmits to the base station a message indicating to the base station that the subscriber unit wants to establish the communications with the base station over the communication channel to be indicated by the base station, the message being transmitted only subsequent to the subscriber unit receiving the indication,

wherein each of the successively transmitted signals and the message are generated using a same code; and

wherein each of the successively transmitted signals is shorter than the message.

2. The subscriber unit of claim **1** wherein all of the transmitted signals are different.

3. The subscriber unit of claim **1** wherein some of the transmitted signals are different.

4. The subscriber unit of claim **1** wherein all of the transmitted signals are the same.

5. The subscriber unit of claim **1** wherein the same code is a spreading code.

6. The subscriber unit of claim **1** wherein the successive transmission of signals by the transmitter facilitates power control when the subscriber unit is first accessing the network.

7. The subscriber unit of claim **1** wherein each of the transmitted signals is generated from a respective portion of a chip sequence.

8. The subscriber unit of claim **1** wherein the transmitter is further configured to transmit the signals such that there is a uniform decibel power level increase between the successively transmitted signals.

9. The subscriber unit of claim **1** wherein the communication channel is indicated by the base station in response to the message.

10. The subscriber unit of claim **1** wherein the message is a call setup message.

11. The subscriber unit of claim **1** wherein the transmitter is further configured such that, subsequent to the subscriber unit receiving the indication, the transmitter transmits a message uniquely identifying the subscriber unit to the base station.

12. The subscriber unit of claim **1** wherein the transmitter is further configured such that, subsequent to the subscriber unit receiving the indication, the transmitter transmits pilot bits to the base station.

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